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This report contains information on national-level science policies, technology strategies, and research and development programs in West European science and technology in general and specifically in civil technology, with particular attention to transportation, energy, chemical manufacturing, industrial automation and technology transfer. The report will focus primarily on France and the Federal Republic of Germany, but will also cover important developments in Italy, the Netherlands, Sweden and other West European countries.

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SCIENCE AND TECHNOLOGY

No. 3

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EEC RESEARCHERS TEST ALTERNATIVE ENERGY TECHNOLOGIES

Duesseldorf WIRTSCHAFTSWOCHE in German No 38, 17 Sep 79 pp 46-52

[Text] In view of the fact that petroleum is becoming scarcer and more expensive all the time, the European countries are being forced to seek new energy sources from which they can supply their industries in the coming century. Besides nuclear energy and coal, the European governments are entertaining hopes above all for new technologies with which the sun's energy can be made usable by man as soon as possible.

Giant space stations parked in the cosmos above Europe catch the sunlight with paddlelike collectors. By means of microwaves similar to the radar waves in use today, they send the bundled energy to receiving stations in Germany, England and France.

Energy supply from space for the countries of the European Community--a vision which in the view of scientists could very well become reality; in 100 years, perhaps. This is too far hence to serve even as just a straw to grasp for the Europeans who require more energy each year.

Oil, inexpensive and superabundant, which after the war transported Europe's industries from boom to boom, will in 30 years be available only in small quantities. Coal, although plentiful, cannot replace oil and gasoline in unlimited fashion because of environmental effects, even after introduction of the newest purification technologies. Nuclear energy, the second pillar of Europe's energy supply for the coming years, remains uncomfortable even for its advocates.

There remains the hope of using the biggest known nuclear reactor, 149 million kilometers away from earth. The utilization of solar energy, so promise the scientists, will be catastrophe-proof and not harmful to the environment.

This makes it all the more surprising to see how hesitantly and with what small means the EC countries are preparing for the transition to a new energy era. Not even a billion marks a year are spent by the EC Commission and member countries for research on new approaches to solar energy. The joint agricultural policy, inefficient and to the consumer's disadvantage, costs the Community of Nine at least DM 20 billion a year.

Since 1977, all of DM 35 million have been at the disposal of a 35-man research team for a 5-year program which is to lead to new utilization of solar energy. They work, eyed suspiciously by the national research bureaucracies, at Ispra in upper Italy, the research station of the EC's atomic authority.

Despite the small means, the EC researchers believe that they can already light the gloomy energy future--with about 300 mirrors. These occupy 7,000 square meters within the area of the Sicilian community of Adrano, a village of 300 people located 40 kilometers inland from Catania.

These mirrors of various dimensions are an important constituent of the first solar power station which the Commission's researchers have erected jointly with the Italian electricity company Enel, and which--as the first on earth--is to supply current to the electric power network in the coming year.

"Eurelios," Europe's first solar power station, works according to a simple principle. The mirrors disposed horizontally on the ground reflect solar rays onto a central steam generator in the top of a 50-meter-high tower. The water vaporized by solar heat produces electricity in a turbogenerator.

The 1000-kilowatt (1-megawatt) capacity of the Adrano pilot installation does at first, however, make it seem like an outsized toy in comparison with the 500- and 1000-megawatt-capacity traditional power stations. And also, the investment of about DM 24 million makes Eurelios too expensive, even if it should at some time really achieve a capacity of 5 megawatts. The capacity limit of such installations, according to scientists' projections, lies at 50 megawatts. The installations can thus, in any event, be used for local energy supply.

Despite their success with Eurelios, the EC scientists warn against excessive hopes; since the capacity of such a power station depends on the size of the mirror field, such installations must encounter geographic difficulties in densely populated Europe. According to an Ispra rule of thumb, a capacity of 100 megawatts requires a mirror field of 1 square kilometer.

If the EC Europeans were to cover their annual requirement of 1 trillion kilowatt-hours of electricity with Eurelios-like power stations, Europe would look like a nightclub dancer's glittering, sequinned dress to the cameras of the satellites.

About 1 percent of the total area of the EC countries would have to be sacrificed for mirror fields, approximately as much land as is already surfaced for Europe's roads today. "Not desirable," comments even Joachim Gretz, solar energy researcher of the Ispra team, with regard to such future expectations.

In addition, such solar power stations always lose usefulness the farther north they are built. While the scientists estimate the annual "energy harvest" in sun-rich Italy at 300 kilowatt-hours per square meter of mirrors, the corresponding average for the Federal Republic is merely 150-200 kilowatt-hours. This is only a little more than the sun would yield in the neighborhood of London--about 100-120 kilowatt-hours.

Consequently, would Eurelios be progress without a future? Surely not. Smaller installations of this kind could soon relieve the electric current needs of communities or even city districts. In the Europe of the future they will be the pegs of a decentralized supply system.

The very large mirror power stations will not, however, be located in Europe, in the view of the EC scientists. As future locations of extended mirror areas, the Ispra researchers have found, for example, regions in which the available space and strong insolation meet almost ideally: the Sahara, an area the size of the United States, or the deserts of Arabia.

The scientists expect that here there will be, in addition to thermomechanical installations of the Eurelios type, new kinds of solar power stations supplying Europe and Africa with energy--power stations which transform sunlight directly into electricity.

According to a majority of the researchers, "photovoltaics" is the trend of the future. In this system sunlight is transformed directly into electric energy by the use of semiconductors, without the high-requirement mirror fields. Ispra researcher Gretz terms this: "Doubtless one of the most elegant technologies."

An expensive elegance: Today a kilowatt-hour of silicon semiconductor technology costs 800 pfennigs. An atomic power station supplies the kilowatt-hour for 5-10 pfennigs.

Semiconductors become even more expensive if their performance is compared with traditional power stations, operated 24 hours a day with oil or coal. Since solar power stations supply energy for only 6 to 8 hours, they are also amortized 3 to 4 times more slowly.

This, experts aver in Europe as well as America, will change within the coming 10 years. In this time, in fact, solar researchers expect the necessary "breakthrough technologies" in photovoltaics, when prices should plummet as a result. And then the kilowatt-hour of electricity supplied by semiconductors with solar insolation will only cost between 20 and 60 pfennigs.

With such prices, photovoltaic solar power stations would have a future in Europe also. This is because, other than the thermomechanical models, they have sufficient capacity with diffuse and moderate sunlight.

However, Europe's energy researchers expect far more than merely a further source of electric current from this type of power station. They expect from photovoltaics the fuel which in the future can be the most important means of powering European industry besides nuclear energy: hydrogen. The cleavage of water into hydrogen and oxygen has not been a technical problem for some time. However, such electrolysis consumes so much energy that hydrogen production is simply not economical at this time.

In the African and Arabian deserts photovoltaic solar power stations are thus supposed to generate this electricity cheaply to make hydrogen production economical, since water as a raw material has for a long time been considered by scientists as the ideal replacement for coal and oil.

With a specific heat 3 times as high as that of oil and gasoline, hydrogen is indicated as secondary energy of the first order. In addition, its storage and transport capabilities constitute further good properties of a secondary energy source.

By the beginning of the next millenary, Europe's researchers believe, power stations in the sun-rich regions of Africa and Arabia will be producing this fuel. Through a network of pipelines which will connect Africa with the European continent, gaseous hydrogen will be pumped into the existing natural gas networks.

Synthetic materials made from hydrogen, such as methanol and ammonia, will be transported to Europe as fuel. Hydrogen as well, liquefied as oil is now, will be supplied to Europe by tankers.

Environmental catastrophes such as those caused today by tanker collisions off Britany or the coast of South America would then be out of the question. Tanker accidents of the future will in fact jeopardize only the captain and crew.

Because hydrogen volatilizes very rapidly during an accident, there will be only two extreme alternatives for future tanker crews: The valuable fuel volatilizes harmlessly in the atmosphere--or a mighty explosion destroys ship and crew.

However, the hydrogen age still lies in the distant future--according to estimates of EC energy researchers, at least 40 years. In what ways, however, will the Community of Nine, which at present uses more than half of the available energy for heating water to under 100° [C] utilize the sun in the next few years?

In their 5-year research project the EC researchers in Ispra have not found much that is encouraging. At first they started with the assumption that solar radiation, which heats water to temperatures of 95 degrees without concentration, could be used for heating houses.

Flat collectors of 40 square meters installed on the roof of a house, according to the scientists, could reduce the household's oil consumption by over half.

To be sure, such solar collectors are not inexpensive. The house owner must at present spend DM 400 per square meter if he wants to re-equip his house for solar heating--all this in the hope that with present oil prices his investment of DM 20,000 to 30,000 will perhaps be amortized in 10-12 years.

This hope is illusory, the Ispra researchers have found. Solar collectors, as offered on the market at this time by European industry, have only a short life. Only a very few of the solar receivers tested in Ispra worked for more than 3 years. Thus, solar heating for the individually owned house, recommended even by German ministers of state, has proved to be a recommendation for an expensive, bad investment.

Above all, economies can be achieved when a house is well insulated. This saves more than the use of solar collectors, as proved by an experiment in Denmark. There 3,500 liters of heating oil were consumed annually in a 10-year-old house. At the beginning of the 1970's, a new house with the same dimensions and the same amenities, but above-average insulation, was built next to the old house. Oil consumption in 12 months: 850 liters.

Nevertheless, solar collectors will contribute to the improvement of Europe's energy balance in the future. But these will be not so much collectors from the factories as solar collectors in nature: plants, which transform sunlight together with carbon dioxide from air and water into sugar, starch and cellulose. If the products of this photosynthesis of plants are fermented, something like methane is formed, a "biomass" which can be used as a fuel.

According to the calculations of the Ispra energy researchers, a German mixed forest grows annually by 1 to 1-1/2 kilograms per square meter. If this wood is fermented, methane is formed with a heating value of up to 3,000 kilocalories per kilogram of wood. The trees have accordingly been able to transform sunlight with extremely low efficiency--0.35 percent--into fuel. In this way 200 billion tons of such "biomass" are produced on earth annually--10 times more than the energy consumed by the population of the world.

An Irish research council has already ascertained in a study that total Irish energy consumption could be assured from 10 percent of the area of the Emerald Isle through such bioconversion.

There are also, however, plants whose efficiency in converting sunlight into energy is appreciably higher than that of the German oak, beech and birch. Sugarcane, corn and soybeans have, according to scientists, an efficiency of 3-4 percent as the most hard-working producers of biomass. The Brazilian government has been financially supporting the construction of installations for fermenting sugarcane since 1975; starting with the coming year, it wants to cover 20 percent of the total fuel demand with the ethyl alcohol thus produced.

However, utilization of biomass is only a beginning toward using the natural capabilities of plants to transform the sun's rays into energy. Theoretically, it is conceivable at this time that plants can be "violated" in such a way that instead of growing they will furnish energy.

Plants, like photovoltaic solar power stations, produce the desired hydrogen. To be sure, this is only for a short time, and then the hydrogen assists with the formation of starch and cellulose. Here man will intervene in the next century. The reaction of light in the plant, in which the water molecule is split into electrons and hydrogen ions, is separated by synthetic means from the succeeding reaction in the dark.

The plant is "trained" to produce hydrogen. Ispra scientists do not consider it at all odd to expect that in 100 years a blooming rape field will impress people out for a walk as, above all, a beautiful power station. Energy researcher Gretz states: "Hydrogen production of this kind would be clean, inexpensive and not harmful to the environment."

The EC energy policy makers will not live to see this beautiful world. Pictures of energy sources harmless to the environment give them little solace in their search for ways in which the growing energy deficit of the Community of Nine can be halted as rapidly as possible in the coming years.

However, there is a region on the EC's northern rim which could ease Europe's energy worries appreciably in the next few decades: Greenland, which as a part of Denmark is a member of the Club of Nine, could become the energy dispenser of the community.

On the cold island, masses of meltwater drop far more than 1,000 meters into the depths annually. Scientists have already calculated the energy potential of these waterfalls: 1 trillion kilowatt-hours per year--the exact amoung of electricity which the 240 million people in the European Community consume annually.

5586
CSO: 3102

USE OF CATTLE DUNG AS ENERGY SOURCE DISCUSSED

Vienna UNSERE UMWELT in German No 32, 1979 pp 5-6

[Unattributed article: "Cattle Dung As Energy Source"]

[Text] The worldwide energy crisis in 1973 intensified the search for "alternate possibilities" of harnessing energy.

In order to assure rapid and effective use of alternate methods of harnessing energy, energy conversion systems already in use were to be applied as far as possible.

The largest portion of energy converters (boilers, motors, turbines and others) work with the relatively expensive and non-renewable fossil fuels, such as oil, coal and gas. Alternate methods working on the basis of materials which resemble these fossil fuels have the greatest chance at early and cost-favorable utilization, since they can be based on technologies which have been tested over quite a number of years.

Biogas for Agriculture

The harnessing of biogas from organic waste materials represents at the present time the only possibility of using an alternate energy source in all energy converters already in existence.

Method

Anerobic fermentation--that is, fermentation without adding oxygen--of decomposable substances, such as liquid animal manure and plant residues, releases per kilogram of organic dry mass between 0.2 Nm^3 and 0.8 Nm^3 of biogas with a lower heating value of 5,000 $kcal/Nm^3$.

The usable part of the gas, the methane (CH_4), corresponds to the natural gas already in use.

Using biogas in conventional gas boilers, gas turbines, motors and so forth does not create any problems from a technical point of view.

In addition, the decomposed organic matter exhibits, as compared to the conventional organic fertilizer, a considerable improvement in fertilizing action, and also guarantees deodorization.

Advantages for the Austrian Economy

By careful estimates a gas volume of approximately 1,000 . 10^6 Nm^3 of biogas could be generated in Austrian agriculture after the short-term utilization of biogas facilities within the next 5 to 7 years. This amount corresponds approximately to the heating value of 500,000 t of diesel oil at a present value of at least 1.5 billion Austrian schillings--or the power of two to three Danube power plants!

Advantages for Agriculture

Depending on the type of cattle and number, agricultural units could save up to 100 percent of overall foreign energy costs for oil, coal, current and so forth with the production of biogas.

In favorable cases, as for example in industrialized, large-scale animal husbandry, even a production of excess energy is conceivable.

Gas Yields in Solaris--Biogas Facilities

Type of animal	Live weight	Gas yield
1 cow	500 kg	0.75 m^3/day
1 pig	80 kg	0.1 m^3/day
10 hens	at 2 kg each	0.1 m^3/day

A farm with, for example, 100 head of breeding cattle at an average weight of 350 kg live weight may expect a possible biogas yield of 60 to 100 Nm^3/day.

This heating value is equivalent to that of 40 to 70 liters of heating oil. Solaris biogas facilities are economically profitable starting at 10 GVE [live weight unit of cattle = 500 g].

The relatively uncomplicated construction of the Solaris biogas facilities also assures interference-free operation and low maintenance costs.

Increased Value Yields by Biogas Facilities

On the basis of experience gained in the Federal Republic of Germany and in Austria, the use of biogas facilities may lead to an increase in economic value yields from animal husbandry by approximately 20 percent.

Even without taking into account the favorable effects on the Austrian trade balance, the use of biogas facilities would also contribute substantially to a strengthening of the agricultural sector.

Since early 1979, the Austrian Solaris Company, which had proven itself for a number of years in the construction of solar facilities, organized the planning, manufacture and sales of biogas facilities for agriculture.

9243

CSO: 3102

AUSTRIA

BIOGAS AS ENERGY SOURCE EXAMINED

Vienna UNSERE UMWELT in German No 32, 1979 pp 6-7

[Article by Prof of Engineering Rudolf Wicha: "Energy From Biogas"]

[Text] The necessity to obtain energy is today a more topical subject than ever before.

It is not because the start of operations in Zwentendorf led to negative results, since this would only have been the first, but rather because energy will with certainty become more expensive in the future. Proof of this was produced last year if one takes into account only the price increases, regardless of possible shortages. Nothing better can happen in our lives than to be able to state that "we are independent--autonomous." Well, to be completely autonomous is hardly possible, but perhaps independent to a large extent. The reprocessing of liquid manure in agriculture already brings an individual who can take advantage of this large step forward on the road toward independence on the basis of his animal stocks.

The generation of biogas:

1. The biogas develops, among other things, in the fermentation process in the manure pits. For example, up to 15 m^3 of biogas can be generated per day from 1,000 liters of liquid manure, with 1 m^3 corresponding to approximately 1 liter of liquid gas, and this liter again being equivalent to one-half liter of premium gasoline.

Nothing is easier in our country than the continuing procurement of the basic raw material of liquid manure, which is always available in sufficient amounts. In airtight containers with approximately 10,000-liter content, a fermentation process develops which heats the manure. This produces bacteria which, in turn, create the combustible methane which can then be used to advantage in the most diversified ways. Natural gas contains approximately 80 percent methane.

The entire explosion-proof low-pressure gas facility is connected to the manure container. With its gas compressor, the gas purification device fed by the water and the gas storage container with high pressure valves, it allows a type of gas recovery which is in principle closely related to the wood-distilling aggregates.

2. The biogas can also be converted into liquid gas and thus into an environmentally acceptable, leadfree fuel for gasoline engines which, in addition, protects the engine.

3. The composition varies with the nature of the organic material decomposed. In each case, the largest component is the simplest hydrocarbon methane (CH_4); additional components are carbon dioxide CO_2), nitrogen (N), hydrogen (H), and some hydrogen sulfide (H_2S). A total of 70 percent of the biogas is methane; the carbon dioxide content depends on the temperature of the decomposition process and decreases in proportion to the temperature.

The heating value lies at 24,700 kj (5,900 kcal/m^3) and can be increased by rinsing out the carbon dioxide to approximately 37,680 kj (9,000 kcal/m^3).

4. Larger farms may have their own gas plant in which they also generate electrical current. Here it is appropriate to have village communes combine and form a joint distributor system.

In areas with a humid climate the drying of hay, corn and grain is done with biogas burners, so-called heating cannons.

This is not even taking into account that the work is quite independent of the weather!

The technology of biogas production has already been mastered perfectly.

The manure is fermented in fermentation containers at a mesophile temperature of 35°C and an average duration of 30 days. The biogas formed is collected in a gas container, whence it is conducted to the areas of utilization. The subsequent energy transformation can proceed by means of conventional gas burners for heat generation in hot water heating facilities or for electrical current generation in a gas motor generator aggregate. The first facilities are amortized in 5 years at the latest.

The long duration (approximately 30 days) until gas formation which has been customary to date can be shortened by appropriate measures. Corresponding tests are already planned at the agricultural university.

Such biogas facilities become economically feasible with at least 20 GVE's (1 GVE = 500 kg of live weight). This amounts to 20 cows or 200 hogs or 3,500 hens.

(Austria has 2.5 million cows and 3.8 million pigs.) From the waste of 1 GVE we can expect a daily amount of 2 m^3 biogas, an amount approximately equivalent to 1 liter of heating oil. The dung of 1 GVE per year then contains an energy potential of approximately 360 liters of heating oil. Accordingly, on an average Austrian farm with 20 GVE's, we find at the present time an energy potential of about 7,000 liters of heating oil per year lying unused.

Biogas is nontoxic and burns without residue. No ashes, no soot, and the burning process can be automated easily, which is of importance given the acute worker shortage in agriculture.

Now, with regard to the MVG Whey Sales and Reprocessing Company.

The company has set itself the task to manufacture the appropriate biogas facilities in the proper size [and] to take on all consulting and servicing for the facilities. The reason for this is simple: The stable units of the whey fatteners correspond to a certain size unit.

The animals, which have been fed liquid whey, have a very uniform feed base. The quality of the manure is thus very uniform and consists, because of the liquid feeding with whey, largely of liquid dung. No additional preparation of the manure with water dung is necessary, which prevents any possible gas loss. The preparation of the manure with biogas, which prevents offensive odors in larger stable units, encourages more farmers to build liquid feed facilities on the most advanced technical bases, which again assures increased whey sales.

This leads to: 1. Greater possibilities for stable building in agriculture. 2. Better utilization of in-house feed production, especially when using whey yeast cream, which in turn leads to further independence of protein components (saving in imports).

3. Generation and use by the agricultural unit of its own additional energy for many purposes.

4. Additional accumulation of excellent bio-manure and possible revenues from it.

Looked at as a whole, this is a further step toward complete recycling.

9243
CSO: 3102

IMPROVED USE, REUSE OF SPENT OIL PROPOSED

Vienna UNSERE UMWELT in German No 32, 1979 pp 23, 24

[Article: "Recycling Possibilities for Spent Oil and Other Mineral Oil Residues"]

[Text] The consumption of energy and raw materials of all kinds cannot go on unchecked ad infinitum. The supplies are every bit as limited as the capacity of our environment to handle the emissions or waste products forming in the process.

Recycling is often praised as a miracle cure for the solution of both problems, like a perpetuum mobile.

We shall make an attempt in the following article to illustrate more clearly the possibilities of reuse for several typical types of mineral oil waste in order to point out on the basis of these examples how narrow in reality the boundaries of an overall economically logical recycling are drawn.

As a first example we shall investigate spent oil utilization: The concept of spent oil is not defined in Austria, but contrary to the concept in Western foreign countries, it usually includes residues of all four types of heating oil, provided they are not considered tank sludge. In the foreign countries of the West, it includes appropriately treated and in part individually collected spent lubricating oil, primarily after use in motors.

This difference in concept always leads to misunderstandings, especially when experience values from the Federal Republic of Germany, shortened by a tenth power, are used as a basis for reuse considerations in Austria. At the present time, spent oil--which, incidentally, in order to bring an end to a legend, has not been discarded for a long time by the tens of tons, but is used as an economically interesting fuel (if we disregard amounts accumulating in small trade or privately, whose removal would not be economically feasible)--has at present the following conventional reuse possibilities:

1. Burning in enterprises which have a fairly large heavy heating-oil or medium heating-oil facility.

The spent-oil accumulation of the enterprise and frequently also that from nearby smaller companies is here admixed, after more or less expensive cleaning, to the heating oil and burned as an energy source.

Environmentalist protests could be made against the substitution of heating oil and spent oil because of the contaminants contained in the lubricating oil additives. However, this can be countered with the fact that compared to many other heating materials the desirable low sulfur content makes up for this drawback.

This type of reuse, of course, is not in the economic interest of professional spent-oil users and spent-oil collectors, but in an economic observation, taking into account all relevant criteria, this is a sensible approach for the following reasons:

From the point of view of a company in which spent oil accumulates, the use of 1 ton of spent oil is the equivalent of approximately 0.8 tons of heating oil, at an average purchasing cost of about 2,000 schillings per ton, thus about 1,600 schillings.

Depending on the distance from a reuse facility, at the present time between 0 and 2,500 schillings per ton--or an average of 1,000 schillings per ton--of spent oil must be estimated for transport and handling costs when turned over to a collector company.

In addition to the company saving about 2,600 schillings per ton of spent oil, the energy saving through the eliminated transport from originator to collector and thence to the disposer or reuser must also be taken into account in national economic observations, every bit as much as that for the transport energy use necessary for the delivery of an equivalent amount of heating oil from the importer or the refinery to this company. Also to be considered is the saving of the heat energy to be spent on crude oil distillation as well as the amount of heating oil substituted by spent oil, which would have to be imported as crude oil or heating oil.

The substitution of heating oil and spent oil directly at the site of accumulation or in a nearby company will therefore not be welcomed by collectors, disposers, resuers, the heating oil and transport trade, but it has increasingly favorable aspects with respect to transport savings and therefore energy savings.

Of course, the preliminary technical prerequisites of the heating facility in which spent oil is burned in conjunction with heating oil must fulfill the environmental protection requirements.

2. Burning in Enterprises Having a Spent-oil Burner

Since the governmental authorization required for installation of spent-oil burners (company facility authorization) is necessary, and thus fundamentally a safeguard is given for boundary values in emissions that are environmentally not excessive, spent-oil burning in such companies corresponds to the economic advantages already described under Point 1, with extensive consideration of environmental protection requirements.

3. Rerefining of Spent Oil and Reuse as Lubricant

This utilization, which is optimum in the sense of the recycling idea, loses some of its attraction at second glance.

First, the situation in Austria is not quite comparable to that of our neighbors. Austria has its own crude oil which, contrary to that used as a rule as a basic oil for lubricant production does not have a paraffin base but a naphthene base.

In addition to certain advantages of this type of crude oil, it has the drawback of being found relatively rarely on a worldwide basis and of not having distinctly good high-temperature properties.

Understandably, lubricants are therefore often generated in Austria from basic oils of the type optimally suited to the use in question. For this reason the spent-oil mixtures accumulating in Austria contain both basic oil types, which causes the positive properties of each individual type to be less noticeable. A rerefined product obtained from such a mixture can therefore not generally be used as a substitute for initial refined products, a fact which naturally results in a lower value and thus a problematic economic feasibility. This establishes the limits of rerefining.

In addition to this specifically Austrian situation, some other points should be considered.

In the refining process, a number of products with very different market prices are obtained from crude oil whose quantity ratio to each other cannot be arbitrarily changed. Considerable sales changes in a fraction affect the yield from the entire remaining group. Lubricating oil fractions, for example, as they necessarily accumulate in crude oil processing, would have to be admixed to heating oils if they cannot be sold as lubricants. It is clear that the group yields necessary to cover all costs would then be distributed in a different way, and would have to be carried by the less expensive heating oils.

The rerefining of spent oil requires a considerable investment which is economically defensible only if sufficient amounts are available; that is, if spent oils are no longer burned but are only rerefined.

This necessity of large flow rates, which cannot be changed, requires a large-scale collection operation, which must be oriented not according to the necessities of environmental protection or cost optimization for the originator, but according to maximum quantity yield. This collecting activity, on the other hand, means in addition to its costliness accompanying transport energy expenditures. The higher fuel expenditure necessary for this would have to be compared in a total evaluation of the corresponding importer savings in basic oil and also be taken into account.

9243
CSO: 3102

DEVELOPMENT OF NEW VEHICLE ENGINE REPORTED

Vienna UNSERE UMWELT in German No 32, 1979 p 28

[Unattributed article: "Engine Development in Austria"]

[Text] As international statistics show, approximately 20 percent of the energy generated all over the world is used in transportation, and about 75 percent of this for road traffic. The necessity of lowering expenditures in energy for transportation as much as possible was taken into account by the Internal Combustion Engines and Measuring Technology Co. Ltd, Professor List, Graz, and a concept for a vehicle engine was developed which, on the one hand, allows savings in mineral oil with equal power and, on the other hand, adheres to the waste gas regulations which have become more stringent in the last years, thus corresponding to better environmental protection conditions.

Whereas diesel engines for cars and light trucks operate at present without exception on the so-called chamber method, invention and development by the AVL are geared to developing a combustion method with direct fuel injection for the diesel engine as well, which will both reduce fuel consumption by 15 to 20 percent and reduce the burden on the environment. The results of the research and development work carried out since 1974 produced a model of a 2-liter prototype engine with four cylinders and direct fuel injection with 46 horsepower.

The results of these research endeavors to date are so encouraging that now the development of the prototype of a four-cylinder and a six-cylinder diesel engine with direct fuel injection is planned. The development costs for the 2-liter model diesel engine have amounted to date to 24.6 million schillings, of which about 7.4 million schillings were raised from loans of the Trade and Industry Research Promotion Fund, and 1.8 million schillings came from the Federal Ministry for Construction and Technology--the Technical Testing Section. The development of prototypes of the four- or six-cylinder diesel engine with direct fuel injection, on the other hand, has

required more intensified development work by the AVL and financial expenditures in the amount of a total of 26.5 million schillings by the end of 1979, which are borne by the Federal Ministry for Science and Research (19.5 million schillings), as well as by the Trade and Industry Research Promotion Fund (7 million schillings). In order to use the research results obtained, an exclusive contract was concluded between the AVL and the Steyr-Daimler-Puch Co, which guarantees to the company exclusive production and sales rights for these light diesel engines for a period of 7 years.

Coordination of the research and development work to be carried out within the framework of this project is to be handled by a coordination committee to which belong one representative each from the Federal Ministry for Science and Research, the Trade and Industry Research Promotion Fund, the AVL and the Steyr-Daimler-Puch Co.

9243
CSO: 3102

USE OF GLASS LININGS IN INDUSTRIAL SCRUBBERS DISCUSSED

Graefelfing ENERGIE in German Jul 79 pp 260-261

[Article by Dr Ekkehard Schacht, Ceramic Chemistry, director of materials development, Montabaur: "Corrosion Protection Through Glass"]

[Text] The components of flue-gas scrubbers are extensively exposed to corrosion from sulfur compounds. Flake-glass coatings provide a noncorrodible layer in such cases because they are made of glass flakes and resin binders. This has been available for years in Japanese markets and is now being offered on the German market as Kera-flake by the Kerachemi [Ceramic Chemistry] Co.

With a special manufacturing process it is possible to shape C-glass from the melt into lamina with a thickness of 0.002-0.005 mm and a diameter of 3.0-3.5 mm. The density of such lamina is 2.5 g/cm^3. Smaller particle sizes down to 0.4 mm diameter can be produced by pulverizing these glass flakes. Because of the lamina-shaped structure of the solid particles, suspensions of glass flakes in liquid media show pronounced orientation phenomena in flow processes. The lamina group themselves in certain directions according to the shear gradient. Thus, extremely advantageous properties can be achieved with the use of a suitable coating technique.

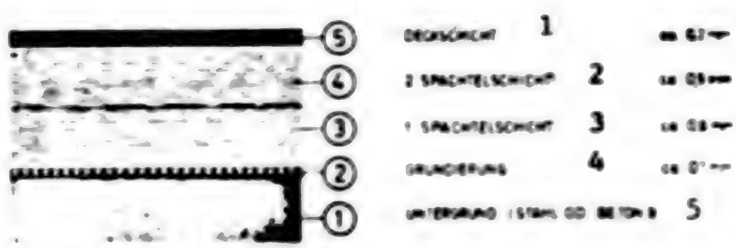
All substances that are suitable as binders for glass fibers also lend themselves to use as binders for glass flakes. Among them are unsaturated polyester resins, bisphenol polyester resins, hetacid polyester resins, vinylester resins and epoxy resins.

All these binders differ in respect to their thermal and chemical resistance and their costs. Thus, one is in a position to adapt coatings to the specific application purpose.

The actual coating materials are pasty masses of filler which, by way of comparison, are also familiar from other synthetic resins. In the case of unsaturated polyester resins and vinylester resins, hardening takes

place via radical polymerization and in the case of epoxy resins by polyaddition. The respective hardening agents are added just before use. Accordingly, the dropping time of the mass is limited; it must be applied to the base within 30-60 minutes. Final hardening takes place at room temperature and takes anywhere from hours to days. The process is accelerated by higher temperatures.

The structure of a complete flake-glass coating is illustrated in the diagram.



Schematic Diagram of a Flake Glass Coating

Key:

1. Cover layer, 0.2 mm
2. Second layer of filler, ca. 0.9 mm
3. First layer of filler, ca. 0.9 mm
4. Primer, ca. 0.1 mm
5. Base (steel or concrete)

The coating is structured as follows:

The steel base is sandblasted to a metallic shine;

Shortly after that, a primer appropriate to the coating system being used is applied by brush, roller or spray;

After that hardens, the first filler coat of the actual flake-glass coating with a thickness of about 0.9 mm is applied; in the process the catalyzed mass is applied to the base, smoothed and worked while it is still fresh in such a way that voids are removed and there is ideal parallel alignment of the lamina;

Then comes a second application of filler which is worked just like the first one;

Finally, the cover layer (coloring is also possible) is then applied with a brush or roller; in special cases, thin glass fibers or fibers of carbon are also incorporated;

Testing for pore density with an induction coil is the final stage in any coating job.

Properties of the Flake-Glass Coatings

The coating masses are differentiated especially on the basis of the kind of binder. The types listed in Table 1 have proven to be especially good for use in technical corrosion protection.

Table 1

Coating Type	Binder	Chemical	Conditions of Use Thermal Liquid	°C Gas	Other
Kera-Flake 3	unsaturated iso-phthalic acid polyester resin	acids	80	90	--
Kera-Flake 4	bisphenol polyester resin	acids alkali	80	90	--
Kera-Flake 5H	"Het" acid	strong acid, oxidizing acid	100	120	flame-resistant
Kera-Flake 6R	vinylester	acids alkali	90	100	--
Kera-Flake 6H	vinylester	acids solvents	120	150	heat
Kera-Flake 6S	vinylester	strong acids alkali	110	130	flame-resistant
Kera-Flake 100	epoxy resins	alkali weak acids, salts	70	80	

100 Flakes Per Millimeter

Among these seven coating types, Kera-Flake 6R has the greatest range of use and is most frequently used. Table 2 provides some physical data for this type of coating.

Table 2

Physical Properties of Kera-Flake 6R

Property	Test Method	Unit	Value
Tensile strength	DIN [German industrial standard] 53 455	N/mm^2	40
Flexural rigidity	DIN 53 452	N/mm2	80
Elasticity modulus	DIN 53 457 (flexure)	N/mm^2	8,000
Adhesive strength (steel)	Shearing	N/mm^2	13
Abrasion resistance	Taber (weight loss)	mg	40
Thermal expansion coefficient		K^{-1}	2×10^{-5}
Steam permeability	ASTM-E 96-66 [American Society of Testing Materials, Misc. Subjects]	g/m^2h Torr	0.01

The fact that a number of properties are anisotropic is a special advantage in these coatings. This is due to the fact that the thin flakelike glass particles, on the basis of their form and the method of application, are aligned strictly parallel to the coated surface. The amount of binder between the individual flakes is relatively small in the directions parallel to the surface. It is clearly higher when vertical to the surface of the base. It has been established that approximately 100 glass flakes lie on top of each other in every millimeter of layer thickness; the gaps are filled with binder.

Thus, in this multi-substance system, the glass flakes form, to a certain extent, a two-dimensional framework for the synthetic resin phase.

First of all, this anisotropy is noted as being advantageous in the shrinking during hardening. Because of the good bond between resin and glass flakes, the length change in the directions parallel to the surface is very greatly hindered, whereas it can have an unhindered effect when vertical to it. Because of this situation, residual stress is virtually excluded.

The thermal expansion coefficient is also anisotropic in the same manner. In the planes parallel to the surface it is clearly smaller than when vertical to it. This can be explained by the fact that if the temperature is raised, no harmful stress occurs which could result in the separation of the coating.

An additional advantage of the lamina-shaped structure of the filler is to be found in the fact that diffusing media have to take a very long path around the individual glass lamina in order to get to the base. The resistance to diffusion is, therefore, extremely high with such coatings.

The coating is also highly resistant to mechanical effects. Shock or impact causes only small local damage which can easily be repaired. Friction produces only modest abrasion or small scratches and mars, respectively, since the glass lamina are very resistant to such influences.

Finally, it must also be stressed that the coatings have extremely high electrical resistance. This makes possible repeated testing for pore density with the induction coil.

A further advantage is the short hardening time. In case of damage, repairs are possible in a short period of time.

The chemical resistance of flake-glass coatings is also included in general outlines in Table 1. Basically it is determined by the binder. Thus, coatings with unsaturated isophthalic acid esters should be used primarily with mild stress by acids or neutral substances. The well-known higher resistance to unsaturated polyester resins which contain bisphenol permits their use even if there are stronger stresses by acids and lyes. Hetacid-containing polyester resins are especially resistant to oxidative stresses; for example, nitric acid, chromic acid and the like.

Coatings containing vinylester are characterized primarily by their high resistance to acids and lyes (Type 6R). Because of the chemical structure, the vinylester used in the Kera-Flake 6H can be used with high temperatures, but not with alkaline stress. In contrast to other binders, it also resists stress by a number of solvents. Epoxy resin binders are especially good against alkaline stresses and in many cases are also resistant to acidic stresses.

Suitable for Flue-Gas Scrubbers

Flake-glass coatings are used to protect containers, equipment and piping used in the chemical industry. According to the extent of the stress, they are used either as the only protection or in combination with an appropriately resistant lining.

Flake-glass coatings have proven themselves to be especially good in flue-gas scrubbers which are coupled to outlets of coal or oil power plants, in order to reduce the environmental damage from sulfur dioxide.

Such systems always consist of a cooler, an absorber, flue-gas pipes and containers coupled to outlets for processing the absorber liquid (gypsum production).

Flue-gas and absorption liquid have temperatures between 60 and 80°C. The preferred flake-glass coating for the absorber is Kera-Flake 6R. For the most part, additional layers of protection against mechanical stress are not necessary. Nonetheless, formation of a surface on the horizontal areas that is resistant to wear and tear is recommended if limestone is used as the neutralizing agent.

The flue-gas pipes, which take the gas from the absorber to the smokestack, must likewise be protected since the gas tends to form a condensate because of the high water content. Frequently the gas is also reheated following the absorber in order to inhibit the formation of condensate in the smokestack and the formation of a flue-gas streamer. The temperatures of the gas following heating run between 105 and 150°C. For this reason, for the most part Kera-Flake 6H is used for flue-gas conduits.

In plants that produce gypsum a number of devices and containers with flake-glass coatings also need protection against corrosion. Thus, for example, storage tanks for the absorption medium and the oxidation tower, in which the calcium sulfite is oxidized to calcium sulfate, are equipped with a flake-glass coating. Since the temperatures in this instance do not exceed 60-80°C, the standard type, Kera-Flake 6R, is used.

Flue-gas scrubbers are not only coupled to outlets of power plants for coal and oil, they are also incorporated into sintering plants used to produce iron. The chemical conditions in this case are similar to those in the power plant systems, but a stronger fluorine content is frequently seen in the cooling and absorption fluid. Also, the dust content of these flue-gases is frequently greater than in power plants. This fact must be taken into account in the design of the coating.

Tested in Japan

Because they are composed of glass flakes and resin binders, flake-glass coatings are protective coatings for structural units of steel and steel concrete which are affected by corrosion. They have been used extensively for many years in the Japanese market under the name Fuji-Flake to protect flue-gas scrubbers and recently are finding use in the same sector in Germany under the name Kera-Flake. Further areas of application for flake-glass coatings are present in many sectors of other industries in which corrosive media also have to be stored, transported or used.

12124
CSO: 3102

SOME FACETS OF 1980 RESEARCH BUDGET DESCRIBED

Paris AFP SCIENCE in French 6 Sep 79 pp 2, 3

/Text/ The 1980 draft budget for research includes, it is believed, the creation of some 709 new jobs, 374 of which are research positions.

To these are added 597 nonlisted jobs.

The funds for maintenance included in the framework of the research package amount to 8,235 million francs (in contrast to 7,251 million francs in 1979). The funds authorized for programs will be 6,244 MF (as opposed to 6,014 in 1979).

The total will be approximately 15 billion francs.

A particular effort will be made in 1980 to promote the development of scientific and technical cooperation with our principal partners. For this purpose a program contract will be established between the Ministry of Foreign Affairs and the DGRSGT.

--Young scientists will have greater access to research, due, in particular to the encouragement of mobility.

--Research efforts will be oriented in veiw of valorizing the scientific and technological gains developed (information and communication technology, spatial, oceanographic and biological technologies) and to intensify the effort in fields with great impacts on obtaining energy and raw materials.

--In order to improve the effectiveness and coherence of research, the elaboration of program budgets will be encouraged in research organisms and specific funding will be granted to laboratories which will cooperate with others in programs which conform to the research priorities.

--The organization of "scientific interest groups," which permit scientists from different fields to work in common without establishing new organisms, will be developed in order to encourage decentralization of responsibilities and cooperation between laboratories, between organizations, and between private and public sectors.

The president of the republic emphasized the necessity to put the French research effort in a long-term scientific and technical perspective encompasing the largest international view.

He asked the secretary of state for research to unite the elements of this prospective in the form of a "white paper on the contributions of French scientific research for the 1980/1990 period." This white paper, which will be associated notably with the Academy of Sciences, will be published in the spring of 1980. Its periodical publication would be best foreseen by having a permanent report of French science and technology. Hereafter, a 10-year strategy of research programs would be a periodical reevaluation and reactualization of these programs, for example, every 3 years.

9128
CSO: 3102

MAJOR POINTS OF 10-YEAR RESEARCH PROGRAM OUTLINED

Paris AFP SCIENCES in French 6 Sep 79 pp 1, 2

/Text/ Mr Pierre Aigrain, secretary of state for research, presented the Council of Ministers on 1 August a report outlining the main points of research for the next 10 years. The main points of this report published by the Elysee after presentation to the council include:

The goal that France must set for herself is to become first among industrial nations in the quality, effectiveness, and volume of research. The development and valorization of research efforts will thus permit not only a general increase in knowledge, but will also constitute an essential gain for our country to maintain its capacity of growth and well-being in the new world economic situation.

The secretary of state, after having outlined the measures adopted since 1975, presented the general orientation which had been approved by the Council of Ministers.

--Public research funds will grow during the next few years at a pace such that the part of PIB of France assigned to research will compare progressively with that attained in industrialized countries of comparable dimensions and the most active in research.

This strategy of research would depend on a white paper, periodically brought up to date as a function of research development and results, as well as deficiencies, and the socioeconomic imperatives of French society.

A preliminary rough draft of such a paper appeared last June, in the form of a report of synthesis on the state of French science and technology, a real "instrumental panel" of French effort in this field in comparison with that made on an international level.

In the preparation of the 10-year program of research, an important part was played by the French scientific missions to foreign countries, whose work of synthesis was very useful.

On 13 September 1979, at 1500 during a press conference on the research budget for 1980, Mr Pierre Aigrain will more fully explain the 10-year research plan.

9128
CSO: 3102

DETAILS OF 1980 RESEARCH BUDGET PRESENTED

Paris AFP SCIENCES in French 13 Sep 79 pp 6-13

[Text] Paris - Draft research budget for 1980
Mr Pierre Aigrain, state secretary for the research was to present the draft research budget for 1980 on Thursday afternoon 13 September.

It will be noted that program appropriations for the research package increased in 1980 by 10.5 percent in relation to 1979 and those of the strict research package by 11.5 percent.

Of the 6644,241 millions of francs 418.6 millions are allocated to computer industries and applications and the rest is distributed in the following manner:

--1642.8 for CEA of which 1262.8 MF will go for research
--1157.7 MF for CNES
--3425.1 MF for other organizations of which 1358.5 MF now will go for program maintenance, 1417.7 for contracts and 560.5 MF for equipment and computation machines.

In connection with CEA and CNES the change in credits granted to them takes into account, besides the financing of programs they conduct, the modifications of the budget changes to which these credits correspond. Because of this, the appropriations in 1980 are not strictly comparable to those of 1979.

For other organizations of the research package the 1980 draft budget project forsees a more rapid progression than the average growth of credits for the maintenance of programs which assure the running costs of laboratories.

As to the running cost appropriations, 84.6 MF of new measures will allow the creation of 670 new jobs of which 374 are research posts, representing a rate of creation of research jobs of 2.7 percent, and 296 are posts for technical and administrative engineers representing an increase of staff of 1.1 percent.

While maintaining the regularity of rhythm in the creation of research jobs the 1980 budget project indicates a special effort to achieve better equilibrium between creation of research posts and creation of ITA posts (engineers, technicians, administrators).

France Research Project

Evolution of research and development credits
subject to interministerial coordination

Program authorizations

(in millions of francs)

Ministries and Agencies*	A.P. 1978 (1)	A.P. 1979 (2)	A.P. 1980
State Secretary for Research	701,175	415,515	436,241
DGRST			
Research Fund	382,175	370,01[illegible]	436,241
Aid to development	319,000	45,500	(3)
Industry	2,388,098	3,112,701	3,602,330
CEA	1,135,570	1,400,000	1,642,834
Research	(890,500)	(1,109,400)	(1,262,834)
Other activities	(245,070)	(290,600)	(380,000)
CNES	938,778	991,067	1,157,680
CNEXO	137,783	149,368	164,983
IRIA	54,518	35,099	39,187
School of Mining	6,200	6,200	5,900
IRCHA	8,260	8,650	8,650
BRGM	23,960	26,660	30,660
COMES	-	63,266	75,170
Chapter 56-00	6,540	6,202	5,352
Chapter 66-01	76,489	426,189	471,914
of which ANVAR			
article 51	-	-	401,700
article 52	-	-	15,000
Cooperation	71,600	77,690	86,690
ORSTOM	33,100	36,090	40,790
GERDAT	38,500	41,600	45,900
Agriculture	150,760	166,896	189,713
INRA	142,000	147,896	170,713
CNEEMA	3,530	3,680	3,680
ACTA	5,230	5,320	5,320
I.A.A.	-	10,000	10,000
Environment and Human Ecology	86,270	83,334	82,673
Environment	26,401	25,002	24,888
CSTB	12,530	13,380	16,380
LCPC	13,690	13,890	10,890
Others	33,649	31,062	30,515

*[Expansions for acronyms will be found following the text]

	A.P. 1978 (1)	A.P. 1979 (2)	A.P. 1980	
Transport	172,550	191,565	186,078	
I.S.T.P.M.	7,170	7,990	8,600	
I.R.T.	26,720	27,672	27,170	
D.M.	17,330	22,330	20,530	
Others	121,330	133,663	129,778	
Health and Social Security	240,400	276,531	278,880	
INSERM	171,683	204,689	234,690	
SCPRI	6,100	6,485	6,480	
Pasteur Institute Paris	52,917	59,177	29,750	(4)
Pasteur Institute Lille	1,950	2,010	4,010	
Pasteur Institute Overseas	2,590	3,210	2,490	(4)
Curie Institute	5,160	0,960	1,460	
Universities	1,114,636	1,203,728	1,308,919	
CNRS	734,636	796,510	874,199	
Research Mission	380,000	407,218	834,720	
Culture and the Media	22,280	18,286	19,373	
Other ministries	39,606	37,922	34,702	
DOM-TOM	16,900	17,700	17,700	
Interior	4,347	4,347	2,800	
Justice	2,400	2,219	-	
Labor	5,279	5,975	6,898	
Planning	10,680	7,681	7,304	
Total research package	4,987,381	5,584,168	6,225,599	
Computer industries & applications	585,800	430,739	418,642	
General total	5,573,181	6,014,907	6,644,241	

1) Taking into account annulment ordinance of 11/11/1978 and rectification finance law of 29/12/1978

2) Initial finance law

3) Credits transferred to the Ministry of Industry

4) After transfer to title IV of 39.852 MF for the Pasteur Institutes of Paris and Overseas (37.627 MF and 2.225 MF respectively)

Credits

(‘n millions of francs)

Ministries and Agencies	C.P. 1978 (1)	C.P. 1979 (2)	C.P. 1980
State secretary for research	630,495	495,840	535,601
DGRST			
--Research fund	304,495	271,140	410,601
--Development aid	326,000	224,700	125,000 (3)
Industry	2,407,810	2,941,021	3,371,204
--CEA	1,155,600	1,421,700	1,615,834
--Research	(925,600)	(1,131,700)	(1,235,834)
--Other activities	(230,000)	(290,600)	(380,000)
--CNES	968,778	991,067	1,158,480
--CNEXO	129,883	146,017	157,713
--IRIA	51,800	36,999	32,587
--School of mining	5,200	6,200	5,900
--IRCHA	6,260	8,300	8,650
--BRGM	23,000	25,500	28,600
--COMES	-	48,436	51,900
--Chapter 56-00	6,54	5,302	5,0
--Chapter 64-91	9,00	15	0,214
--Chapter 66-01	49,749	236,50	306,326
of which ANVAR			
article 51	-	-	180,000
article 52	-	-	6,750
Cooperation	72,000	81,000	84,400
--ORSTOM	31,000	39,000	38,400
--GERDAT	41,000	42,000	46,000
Agriculture	135,500	170,786	161,893
--INRA	127,000	153,486	149,913
--CNEEMA	3,500	3,000	3,680
--ACTA	5,000	5,300	3,300
--I.A.A.	-	9,000	5,000
Environment and Human Ecology	74,897	92,277	79,543
--Environment	17,401	25,801	19,388
--CSTB	11,200	11,900	18,000
--LCPC	12,000	13,610	9,000
--Others	34,296	40,966	33,155

	C.P. 1978 (1)	C.P. 1979 (2)	C.P. 1980	
Transports	14',979	182,556	175,238	
--ISTPM	6,600	7,800	8,900	
--IRT	17,6	20,229	29,000	
--DM	17,600	23,000	22,200	
--Others	101,179	131,527	115,138	
Health & Social Security	232,210	272,987	249,695	
--INSERM	168,183	193,815	206,000	
--SCPRT	6,100	6,485	6,480	
--Past[illegible] Institute Paris	48,917	66,187	29,750	(4)
--Pasteur Institute Lille	1,58	2,01	3,515	
--Pasteur Institute Overseas	2,27	3,53	2,490	(4)
--Curie Institute	5,160	0,960	1,460	
Universities	1,024,236	1,269,988	1,268,409	
--CNRS	656,736	862,770	838,689	
--Research Mission	367,500	407,218	429,720	
Culture and the Media	17,160	17,616	19,713	
Other Ministries	34,706	39,110	36,946	
--DOM-TOM	14,900	17,700	17,700	
--Interior	2,577	3,650	4,350	
--Justice	2,190	2,989	1,360	
--Labor	5,529	5,890	6,512	
--Planning	9,780	8,881	7,724	
Total research package	4,771,993	5,563,181	5,983,342	
Computer industries & applications	585,800	423,754	303,642	
	5,357,793	5,986,935	6,286,984	

1) Taking into account annulment ordinance of 11/11/1978 and rectification finance law of 29/12/1978

2) Initial finance law

3) Credits transferred to the Ministry of Industry

4) After transfer to title IV of 39.852 MF for the Pasteur Institutes of Paris and Overseas (37.627 MF and 2.225 MF respectively)

Table II - Credit functions (in millions of francs)

Ministries and organizations	Credits voted 1978 (1)	Credits voted 1979	New measures 1980
Secretary of State for Research			
--DGRST	138,975	153,743	12,289
Industry	2,294,739	2,577,576	208,914
--C.E.A.	1,921,700	2,132,600	177,400
--CNES	191,624	216,000	- 4,300
--CNEXO	51,643	61,931	12,276
--IRIA + CTI	49,733	60,946	10,8[illegible]2
--Mining school	40,649	46,450	1,962
--IRCHA	13,913	15,633	1,983
--BRGM	32,580	36,730	4,766
--BNM	1,494	1,683	0,034
--BNIST	0,981	1,115	0,240
--Central administration	0,422	0,488	0,016
--COMES	-	4,000	2,205
--ANVAR	-	-	2,000
Foreign Affairs	395,808	394,908	34,950
Cooperation	312,992	361,059	50,363
ORSTOM	204,640	238,277	35,309
GERDAT	108,352	122,782	15,054
Agriculture	574,594	657,744	99,262
INRA	555,308	635,627	97,704
CNEEMA	12,517	14,341	0,908
ACTA	3,290	3,820	0,519
Prime research	3,479	3,956	0,131
Environment and Human Ecology	81,252	92,871	11,095
Environment	4,222	4,829	0,104
CSTB	29,423	34,789	5,923
LCPC	29,821	33,763	4,242
Others	17,786	19,490	0,826
Transport	73,104	84,987	9,466
ISTPM	26,559	31,008	4,094
IRT	21,010	24,426	3,153
DM	25,250	28,507	1,934
Others	0,235	1,046	0,285

Health and Social Security	302,897	360,382	102,443
INSERM	291,086	341,543	55,653
SCPRI	11,811	13,283	1,565
Curie Institute	-	5,556	0,671
Pasteur Institute Paris	-	-	42,066 (2)
Pasteur Institute Abroad	-	-	2,488 (2)
Universities	2,151,922	2,496,881	438,113
CNRS	2,098,475	2,432,503	423,100
Research mission	53,447	64,378	15,013
Culture and the Media	22,831	27,672	7,614
Other ministries	40,134	43,193	3,507
Justice	6,987	7,969	0,588
Labor and Employee Participation	16,952	19,627	3,041
DOM-TOM (TAAF)	13,089	12,226	- 0,156
Plan	1,553	1,723	0,034
Interior	0,280	0,297	-
Trade and Crafts	1,273	1,349	-
Total research package	5,389,248	7,251,016	978,016
Computer industries & applications			6,480
			984,496

(1) Taking into account the annulment ordinance of 17/11/1978 and the rectification finance law of 29/12/1978

(2) After transfer of Title IV to Title VI of personnel credits

Evolution by sectors
The itemized evolution of program appropriations from 1979 to 1980 lists:

	1979 (in MF)	1980 (in MF) (2)	Evolution in percent
Space	991.1	1,164.0	17.4
Ocean	206.5	231.2	12.0
Energy and raw materials	838.6	980.6	16.9
--Energy	(788.8)	(926.5)	(17.5)
--Raw materials	(49.8)	(54.1)	(8.6)
Industrial research	851.4	933.6	9.6
Basic physical sciences	750.4	819.0	9.1
Biological sciences	831.1 (1)	932.0	12.1
Social and human sciences	199.0	215.9	8.5
Environment and habitat	254.1	263.2	3.6
International cooperation	128.1	150.6	17.6
Others	494.0	581.3	17.7
TOTAL	5,544.3	6,271.4	13.1

(1) Anticipating modification on addition of credits for personnel at the Pasteur Institutes of Paris and overseas.

(2) Before deduction for inclusion of personnel without tenure and credits, for computer industry and applications (calculation plan)

[Abbreviations in order of occurrence]

CEA--Atomic Energy Commission

CNES--National Center for Space Studies

DGRST--General Delegation for Scientific and Technical Research

CNEXO--National Center for Exploitation of the Oceans

IRIA--Research Institute of Information Processing

BRGM--Bureau of Geological and Mining Exploration

IRCHA--National Institute of Applied Chemical Research

COMES--Solar Energy Commission

ANVAR--National Agency of Research Stabilization

ORSTOM--Bureau of Overseas Scientific and Technical Research

GERDAT--Grouping of Studies and Research

INRA--National Institute of Agricultural Research

CNEEMA--National Center for the Study and Experimentation of Agricultural Machinery

ACTA--[Expansion unknown]

IAA--Agriculture and Food Industries

CSTB--Scientific and Technical Center of Building

LCPC--Central Laboratory of Bridges and Dams

ISTPM--Scientific and Technical Institute of Maritime Fishing

IRT--Transport Research Institute

DM--Meterological Direction

INSERM--National Institute of Health and Medical Research

SCPRI--Central Protection Service Against Ionizing Radiations

CNRS--National Center of Scientific Research

DOM-TOM--Overseas Departments and Territories

CTI--Technical Information Center

BNM--National Meterological Bureau

BNIST--National Bureau of Scientific and Technical Information

8698

CSO: 3102

AREAS OF EMPHASIS FOR 1980 RESEARCH BUDGET OUTLINED

Paris AFP SCIENCES in French 20 Sep 79 pp 2-5

[Text] Research--up 12.2 Percent in 1980

The total research budget, pending adoption by the Parliament, including operations and program authorizations, will be nearly 15 billion francs. This is only the credit submitted under overall research--that is, it does not include aeronautic, CNET [National Center for Telecommunications Studies], or military research. (Thus, for example, in 1979, out of a total credit of 1,136 MF [million francs] for civil aeronautics programs, outside of overall research, 765 MF were given to research and development tasks, compared to 709 MF in 1978 and 692 in 1977.)

During a press conference of 13 September 1979, Pierre Aigrain, secretary of state for research, stated, "Overall, this budget has increased 12.2 percent; that is, it will grow faster than the domestic gross product. This is the first time in years that this has happened with the research budget." Agrain emphasized that the privileged sectors in this budget are those of research in the fields of energy, life sciences, agronomy and agro-alimentary, ocean management and international cooperation. Below are the priorities within each objective.

Aerospace

Within the framework of the space program, a special effort will be made in 1980 to favor programs for research and development, development of a network for satellite tracking, and improvements for the Ariane launcher. In addition, there are plans for a grant for financing of CNES [National Center for Space Studies] participation in the establishment of the capital funds for an organization which will produce and market Ariane launchers.

Ocean

The 1980 budget includes an increase in credit intended for utilization of sea resources managed by the CNEXO [National Center for Exploitation of the Oceans]. Priorities will be research concerning utilization of living

matter and the marine environment. The grant intended for the CNEXO which will be included in this objective is to allow completion of the Mediterranean operations base and continuation of construction of an engine submersible to 6,000 meters (CYANA [expansion unknown]). Proposed ISTPM [Scientific and Technical Institute for Ocean Fishing] credit for 1980 is to build a new laboratory at Arcachon. A particular effort will likewise be made concerning the universities and the CNRS [National Center for Scientific Research].

Energy and Raw Materials

A significant priority is noted in the projected 1980 budget for energy. Nuclear energy programs designed to insure national autonomy in the area of plain water reactors will be accented, as well as research tied to breeder reactors (technology and reprocessing) and mastery of the cycle of nuclear materials (enrichment and reprocessing). In addition, a particular effort will bear on safety of nuclear plants, of the cycle of nuclear matter, of transport and of loss.

Concerning the other sources of energy, the rapid increase of money dedicated to solar energy will be maintained, permitting development of programs relating to the biomass, photochemical cells and the solar habitat. Authorizations for the COMES [Solar Energy Commission] program will increase by 18.8% in 1980, compared to 1979. Research programs on the economics of energy will likewise be privileged in 1980 in the group of industrial, transportation and construction sectors.

As for raw materials, the main effort will bear on prospecting of deposits (geology and geophysical prospecting) and will essentially be conducted by the BRGM [Bureau of Geological and Mining Exploration].

Industrial Research

The projected budget for 1980 in this area aims to insure an equilibrium between development of research on applications of data processing and automation and development research in the other industrial sectors, notably those which are to accompany dissemination of the applications of data processing in these sectors. The effort made since 1979 in favor of research on the applications of data processing will be continued in 1980. In the other sectors, a new procedure to aid innovation as a replacement for both development aid and predevelopment aid will be managed by ANVAR [National Agency of Research Stabilization], which will also be in charge of distribution of the innovation subsidy. Concerning the sector programs for research aid, the programs for industrialization of the building trade (plan construction) and for innovation of transports will be more particularly sustained. Lastly, greater responsibility will be given to the large organizations (CNRS, INRA [National Institute of Agricultural Research], INSERM [National Institute of Health and Medical Research]) which received

additional grants for this purpose. If they so desire, these organizations will be able to sign conventions for this purpose with ANVAR.

Basic Physical Sciences

The 1980 credit set aside for basic physical sciences for CNRS, AEC and the Research Mission of the minister of universities is to begin improvements of laboratory equipment. The AEC and CNRS grants are for carrying out construction of GANIL [large national heavy-ion accelerator] and completion of ORPHEE [expansion unknown] reactor. Beyond this, construction of the millimetric radio astronomy institute could be taken on by the CNES. Last is the equipping of the hydrodynamics and physical mechanics laboratory of the Paris college of physics and industrial chemistry.

Life Sciences

In the life sciences sector, particular priority will be given to basic biology, the major developmental axes of which are cellular and molecular biology, microbiology, biology and inter-cellular data, biology of reproduction and development, and interactions between living organisms and their environment. This will particularly concern the Pasteur Institute of Paris and the CNRS. Development of the major health programs (malignant tumors, heart disease, protection of mother and infant), with an accent on the field of mental health, will be pursued in medical research, where INSERM grants will increase 14.7 percent in 1980. Clinical investigation and public health research will likewise be favored. In the field of agronomy, outside of development of basic biology programs, research in bioclimatology, in mastery of genetic diversity and in soil cartography will be preferred. INRA grants will increase by 15.4 percent in 1980. As for the biotechnologies, research in the pharmaceutical field, in biological and medical engineering and in the agricultural and food industries will be continued and work in the field of genetic engineering (Pasteur Institute, CNRS, INRA, INSERM) will be increased. Particular attention will be paid to evaluation techniques of the ligno-cellulose heritage.

Social and Human Sciences

The entire contractual policy in the social sciences sector was the object of a reexamination in early 1979 which aimed to define a new utilization of incentive resources so as to insure a better distribution of funds over the pluriannual programs entrusted to the most dynamic teams. Within this new framework, the Research Funds of the DGRST [General Delegation for Scientific and Technical Research] will play an essential role. Beyond this is planned a meaningful effort in the field of heritage knowledge and preservation (ministry of culture and communication).

Environment and Development of Space

For this objective, the programs of which essentially concern organizations and procedures relevant to the ministry of the environment and the state of life and to the ministry of transportation, the projected budget for 1980 includes only a limited and selective increase in some programs (building and construction, transport systems), translating the present reorganization phase of this sector.

International Cooperation

Concerning research conducted in cooperation with developing countries, the priorities of the projected 1980 budget bear upon animal production, management of natural environments, medical research (transmissible diseases and nutrition) and technical research. Beyond this, the past developmental work will be continued. The creation of receiving stations at ORSTROM [Bureau of Overseas Scientific and Technical Research] and GERDAT [Grouping of Studies and Research] will allow organization for better participation by the large metropolitan organizations in the cooperative programs. A particular effort will be made in 1980 to favor development of scientific and technical cooperation with our major partners. To this end, a program contract will be established between the foreign affairs ministry and the DGRST. Last, it must be noted that the projected budget for 1980 includes a significant increase in the funds dedicated to scientific and technical data, the interministerial programs of which will be actuated by an interministerial mission placed near the secretary of state for research.

9171
CSO: 3102

DEVELOPMENT OF MULTILAYER CONDUCTORS DISCUSSED

Paris REVUE TECHNIQUE THOMSON-CSF in French No 2, Jan 79 pp 259-280

[Article by C. Val, Hybrid Circuit Department, THOMSON-CSF: "Silk Screened Multilayer Device Using Copper Conductors" (Manuscript received 5 February 1979)]

[Text] Summary. The utilization of materials which do not contain noble metals is a priority economic objective for tomorrow's products. Copper is particularly well suited to the process involving the use of tin, for it exhibits brazability and reliability with respect to Sn-Pb alloys far superior to those obtained with gold and gold alloys.

Test multilayer devices with two conductor levels have undergone all qualification tests, but major difficulties arise if there are more than three layers.

Various changes in the composition of pastes and in baking conditions are still needed before this type of copper-based multilayer device can be mass produced. However, our findings concerning the mechanism governing the formation of bubbles, and discussions with various paste suppliers, suggest that these changes are feasible both economically and rapidly.

The selection of copper is determined by three major reasons:

The solderability of the $^{60}Sn/^{40}Pb$ alloy makes it possible on one hand to obtain metallurgically stable bonds, and on the other, avoids the reliability problems encountered with multilayers based on gold or gold-platinum, which are primarily due to the formation of Au/Sn and Au/In intermetallic compounds in the case of solders based on indium.

Moreover, the theoretical resistivity of gold is 40% higher than that of copper. The dielectric constants of insulating layers are sligr ly lower (K: 6 to 8) than those achieved by dielectrics baked in air (K: 6 to 12). This reduces propagation times and improves the electrical performance of systems.

And finally, the cost of multilayers based on gold and copper seems lower in the latter case, but much less so than might appear at first.

1. Major Problems Raised by the Baking of Copper

The inherent constraints of copper, such as baking in a non-oxidizing atmosphere, the need to bake each layer because of the elimination of solvents by distillation (14 bakes for a multilayer with four conductor levels), and the need to solder to output surfaces, have caused us to determine the thermodynamic limits within which copper does not oxidize.

Calculation of Acceptable Impurity Concentration Limits in Nitrogen

In addition to oxygen, we have considered the case of the contaminants usually encountered in an air-conditioned industrial environment (chlorine and sulfurs). We have determined the concentrations beyond which the formation of compounds with copper is impossible, and have listed all the 14 forms that are stable under operating conditions (1 atm atmospheric pressure and temperatures between 20 and 1000 °C):

Cu, CuO, Cu_2O

Cl_2, $CuCl_2$, $CuCl$, HCl

S_2, CuS, Cu_2S, H_2S

O_2, H_2, H_2O

In the light of the most recent thermodynamic data, 24 chemical reactions can be envisaged [2 to 8]. Of these, we consider only the minimum number of reactions which involve the 14 compounds. Nine equations are sufficient to describe the system, and are shown in table 1.

The partial pressures of oxygen, chlorine, and sulfur are calculated by means of a program which we developed for gas phase reductions [9].

The existence domain for copper is shown in figure 1, from which it can be seen that at the maximum baking temperature for copper (1000 °C), the O_2, Cl_2, and S_2 concentrations in the nitrogen must all be below 1.10^{-6}.

Nature of polluting gas	Concentration in nitrogen (10^{-6})
O_2	0.5
Cl_2	0.15
S_2	0.03

These levels of purity are impossible to maintain industrially in a silk screening oven.

Table I

N°	Réactions (A)	Domaine de température (B) (K)
1	$\langle Cu_2O \rangle + 1/2\,(O_2) \rightarrow 2\,\langle CuO \rangle$	298-1 357
2	$\langle CuO \rangle + (H_2) \rightarrow \langle Cu \rangle + (H_2O)$	298-1 456
3	$(H_2) + 1/2\,(O_2) \rightarrow (H_2O)$	298-2 500
4	$\langle CuCl_2 \rangle \rightarrow \langle CuCl \rangle + 1/2\,(Cl_2)$	298- 703
4'	$\langle CuCl_2 \rangle \rightarrow \{ CuCl \} + 1/2\,(Cl_2)$	703-1 356
5	$\langle CuCl \rangle + 1/2\,(H_2) \rightarrow \langle Cu \rangle + (HCl)$	298- 703
5'	$\{ CuCl \} + 1/2\,(H_2) \rightarrow \langle Cu \rangle + (HCl)$	703-1 356
6	$(H_2) + (Cl_2) \rightarrow 2\,(HCl)$	298-2 100
7	$\langle Cu_2S \rangle + 1/2\,(S_2) \rightarrow 2\,\langle CuS \rangle$	623-1 360
8	$\langle CuS \rangle + (H_2) \rightarrow \langle Cu \rangle + (H_2S)$	298-1 356
9	$(H_2) + 1/2\,(S_2) \rightarrow (H_2S)$	298-1 750

( ) gazeux. { } liquide. ⟨ ⟩ solide. (C) (D) (E)

Key: (A) Reactions
(B) Temperature range (K)
(C) Gas
(D) Liquid
(E) Solid

We know that the thermodynamic data can only provide information about whether a compound can or cannot be formed, but offers no information on the kinetics of these reactions. However, we did observe that during processing, the copper could become oxidized even though we did not change the composition of the nitrogen drawn from the distillation of liquid nitrogen (about 50 m of tubing). A bypass system allowing a switch-over to bottled nitrogen ($O_2 + H_2O < 5.10^{-6}$) made it possible to once more obtain a non-oxidized copper (visually).

The second specific problem of copper is its brazability.

Brazability of Copper

After using the meniscograph method with samples of the same size as those described by Jellison and Pantanelli [10, 11], we found that the method is not sufficiently sensitive for conductors with similar values of wettability; we therefore used only an optical examination of bonded surfaces.

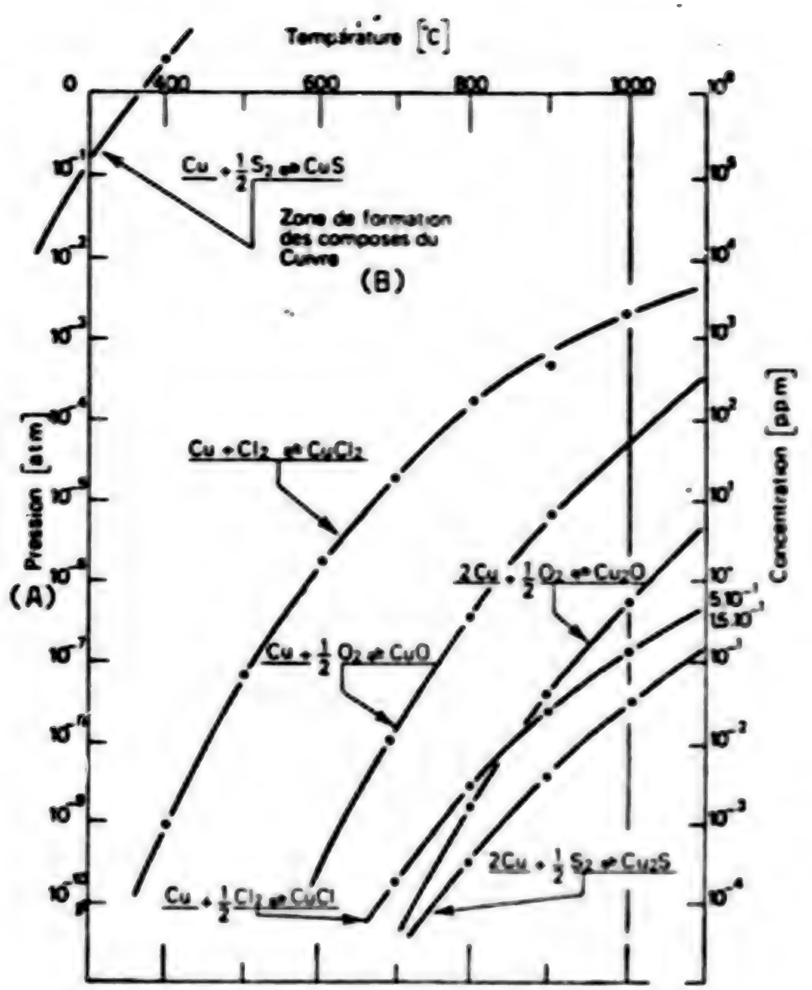


Figure 1. Existence zone for copper, as a function of O_2, Cl_2, and S_2 concentrations.

Key: (A) Pressure (atm)
(B) Zone of formation of copper compounds

In all cases, copper on alumina or on dielectric, and after one or several bakes, very poor wetting is observed, as had already been pointed out by K. Kurzweil and F. Franconville [12]. The usual conditions for tinning are as follows:

Preheating to 150 °C with PC 21 or ALPHA 611 flux;

Dipping in a ^{60}Sn/^{40}Pb bath at 235 ± 5 °C for 5 s.

A stripping method was developed after the cause for non-wetting was determined by Auger Electron Spectrometry of the copper surface. The analysis showed the presence of silico-aluminates (Al_2O_3 and SiO_2) segregates over thicknesses of about 50 °A, and a slight surface contamination of carbon and calcium. The copper oxidation decreases very rapidly with depth, the oxygen concentration being less than 25% at a depth of 50 °A. The glass encountered at the surface is found on the copper deposited both on alumina and on a dielectric, and is therefore very probably caused by the vitreous phase present in the copper. It was possible to eliminate this glass either by mechanical rubbing, or by chemical stripping through attack of the underlying copper (in situ attack). We have used this method and compared the effect of four chemical solutions:

Copper Brite (overly corrosive action, ultimately);
Solder Wet 2430 (Alpha Metal) (acceptable);
HC1N/10 (acceptable);
DILAC (under evaluation).

The qualification tests were conducted with Solder Wet 2430, followed by cleaning with flowing cold, and then tepid, water, and ending with a dip in deionized water. The total amount of ions remaining on the parts was determined by measuring the solder equivalent with an integrating conductivity meter (Ionograph).

2. Investigation

The samples were 2" × 1", and included two conductive layers separated by a dielectric layer; they made it possible to study the influence of separate variables.

The topologic characteristics of the samples are given in table II.

Table II

Conductor width	127 µm, 254 µm, 381 µm
Window dimensions	381 to 762 µm
Window shape	square and octagonal
Number of crossings	300
Condenser	4, in surface ratios of 1 to 16, beginning with 1.6 mm^2
Adherence measurable at 3 levels	copper/alumina, copper/dielectric, dielectric/alumina

Fabrication Conditions

The samples were printed under the usual conditions shown in table III, and baked in a six-zone, N_2 atmosphere furnace, with a 10 cm-wide belt (BTU).

Table III

Parameter	Conductive layer	Dielectric layer
Outside of contact (mm)	0.5	0.5
Squeegee hardness (shore)	80	80
Squeegee speed (cm/s)	4	4
Screen: mesh	325	200
emulsion (µm)	20-25	10-25
orientation (^{o})	45	45
dimension (mm)	200 x 175	

The silk screening order and that of the bakes was considered for four cases as shown in table IV.

Table IV

Order of bakes	Cases 1	2	3	4
Bake 1	Cu_1 R	Cu_1	Cu_1	Cu_1
Bake 2	D_1	R D_1	D_1 R	D_1
Bake 3	D_2	D_2	D_2	D_2 R
Bake 4	Cu_2	Cu_2	Cu_2	Cu_2

Cu_1, 1st conductor plane; Cu_2, 2nd conductor plane; R, copper reload at windows; D_{11}, 1st dielectric layer; D_{12}, 2nd dielectric layer; Cu_{n1}, nth conductor plane; D_{n2}, nth dielectric plane.

We selected case No 2 because the silk screening of the reloads is easier, and rebakes are reduced, as compared to case No 1.

The tests were conducted in order to select the various suppliers of the system (copper + dielectric) according to the criteria listed in table V.

The types of pastes retained after discussion with the suppliers are shown in table VI.

Table V

Input parameters		Output parameters
1. Type of paste:	ESL	1. Conductor:
	Cermalloy	
ESL	LEP (F)	Appearance
Cermalloy	Du Pont	Dimension
Du Pont	"	Resistance/□
LEP	"	TCR
	"	Adherence
2. Fabrication:	"	Chemical analysis
Drying temperature	"	Brazability
Drying time	"	ε
Peak temperature	"	2. Dielectric:
Sensitivity to rebake	"	Window shape
	"	Dimension
	"	
3. Industrial parameter:	"	Ri
Influence of oven loading	"	U breakdown
(under investigation)	Du Pont	3. 2000 h qualification

Table VI

Fournisseur (A)	Condensateur cuivre (B)	Diélectrique (C)	Conditions cuisson (D)	
			Température du palier (°C) (E)	Pureté de l'atmosphère (F)
Électro-Science Laboratories, Inc	EX 2310 lot 669-9-1	4901 lot 621-46	850-1 050	N_2 purifié
Cermalloy	7029 lot 761	NPS 7115 lot 861	850- 900	N_2 purifié (G)
Du Pont de Nemours	9923 lot G 113 097	9949 lot G 113 077	900- 925	N_2 (moins de 10.10^{-6} O_2) (H)
LEP (France)	Expérimental	(I) En développement	900-1 000	N_2 purifié

Key: (A) Supplier
(B) Copper condenser
(C) Dielectric
(D) Baking conditions
(E) Flat zone temperature (°C)
(F) Atmosphere purity
(G) Purified
(H) less than 10.10^{-6} O_2
(I) Under development

Table VII

Supplier	Theoretical width 127 µm	254 µm	381 µm
Du Pont	Triangular	Trapezoidal	Trapezoidal
ESL	Trapezoidal	Trapezoidal	Flattened trapezoidal
Cermalloy	Curvilinear rectangular	Curvilinear rectangular	Curvilinear rectangular
LEP	Triangular	Trapezoidal	Rectangular

Selection of Copper Types

As can be seen from figure 3, only the suppliers LEP and Du Pont offer acceptable rheologies and dimensions; the conductor shape for the other suppliers is quite variable (table VII).

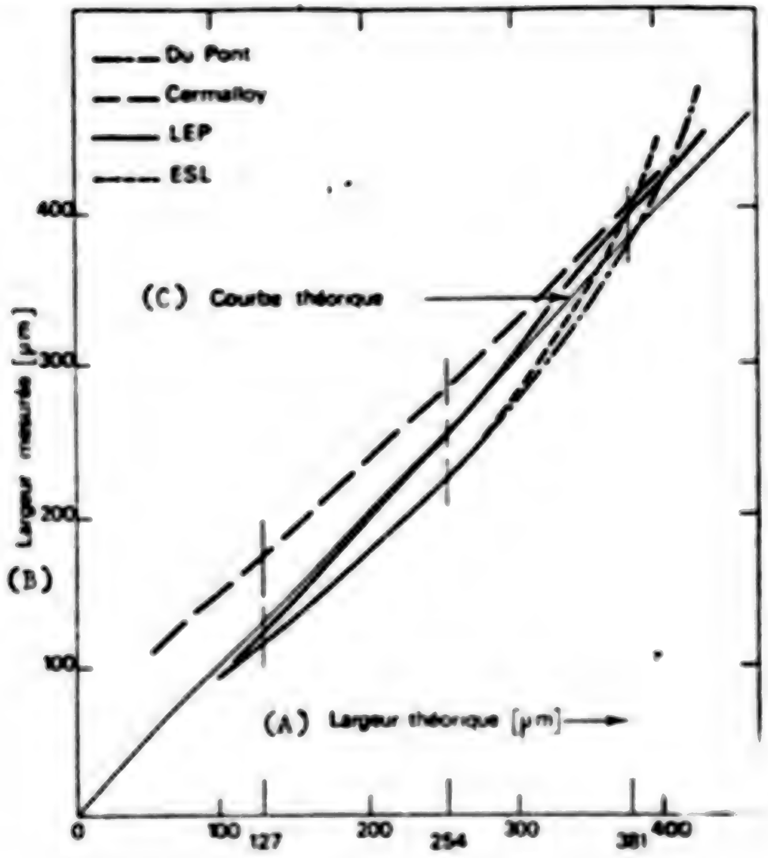


Figure 3. Measured width as a function of theoretical width.

Key: (A) Theoretical width (B) Measured width (C) Theoretical curve

The measurement of resistances per square has enabled us on one hand to classify the quality of the conductors, and on the other hand, to determine sensitivity to fabrication parameters (drying and baking). But it should first be stated that the normalization of R/□ for a thickness of 25 µm in cross section does not have a physical meaning, because the cross sections of conductors for dimensions smaller than 250 µm are not rectangular.

Table VIII

	(A) Largeur du conducteur (µm)		
	Section triangulaire (B) 127	(C) Section trapézoïdale 254	381
Longueur conducteur (mm) (D)	43,5	43,5	96,2
Largeur conducteur (mm) (E)	0,11	0,22	0,37
Épaisseur (µm) (F)	15	17	14
Résistance/□ (mΩ/□) (G)	3,00	1,91	1,98
Résistivité calculée (µΩ cm) (H)	4,50	3,25	2,77
Section réelle (mm^2).10^4 (I)	0,98	3,40	5,18
Résistivité corrigée (µΩ cm) (J)	2,70	2,95	2,77
Surface latérale (Sl) (mm^2) (K)	4,8	11,0	38,3
Volume (Vl) (mm^3) (L)	0,036	0,163	0,50
K = Sl/Vl (mm^{-1})	133,3	67,5	76,6

Key: (A) Conductor width; (B) Triangular cross section; (C) Trapezoidal cross section; (D) Conductor length; (E) Conductor width; (F) Thickness; (G) Resistance; (H) Calculated resistivity; (I) Real cross section; (J) Corrected resistivity; (K) Lateral area; (L) Volume

If the measured resistivities are corrected as shown in table VIII (Du Pont copper case), it can be seen in figure 4 that the corrected resistivity, taking into consideration the real cross section, leads to values that are less dependent on the width of the conductor. In other cases, the relative resistivity of silk screened copper is between 1.3 and 1.9 of the resistivity of bulk copper.

Correlating the ratio lateral area/conductor volume to the total resistance of the conductors (figure 5), we observe a quasi linear relation, which supports the predominant role played by the surface reactions already found by Auger analysis, in terms of resistivity per silk screened square.

We believe that paste suppliers should furnish the R/□ values of conductors, specifying their width, their cross section shape, and the baked thickness.

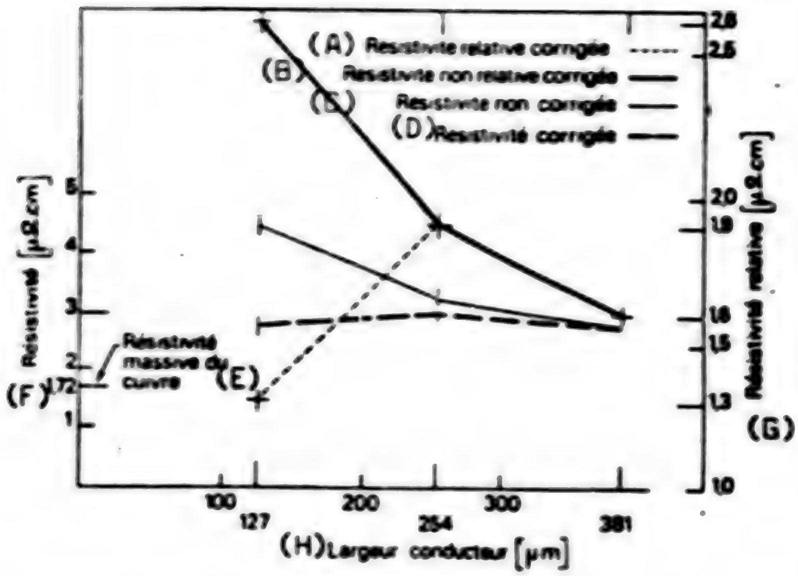


Figure 4. Resistivity of conductors as a function of width.

Key: (A) Corrected relative resistivity
(B) Corrected non-relative resistivity
(C) Uncorrected resistivity
(D) Corrected resistivity
(E) Bulk copper resistivity
(F) Resistivity
(G) Relative resistivity
(H) Conductor width

Paste Sensitivity to Drying

Drying temperatures and times were extended beyond both limits suggested by vendors (see table IX).

Du Pont and ESL show very little sensitivity to drying conditions.

Sensitivity to Baking Conditions

The suppliers' baking profiles were reproduced, and nitrogen flow rates were determined for various zones of the furnace based on resistivity and TCR measurements of the copper conductors. This TCR measurement (approximately 3000.10^{-6}) is not sufficiently sensitive to determine the operating points of the furnace, but is sensitive to the number of rebakes.

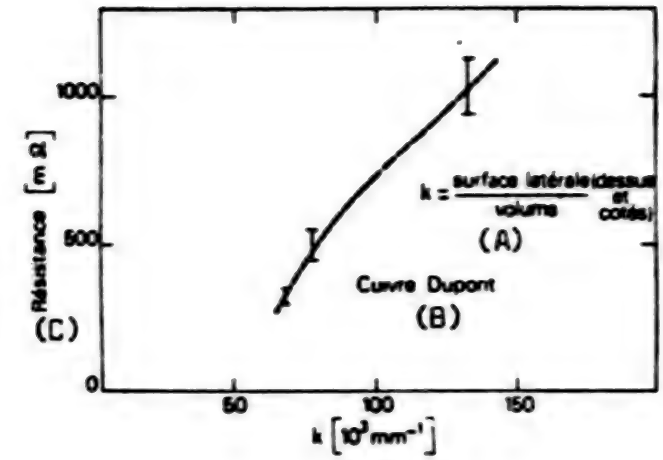


Figure 5. Conductor resistance as a function of the ratio lateral area/volume.

Key: (A) k = lateral area (top and sides)/volume
(B) Dupont copper
(C) Resistance

Table IX

(B) Type de pâte	(A) Conditions			
	Température de séchage (C) (°C)		Durée (D) (mn)	
	Conseillée (E)	Essayée (F)	Conseillée (E)	Essayée (F)
Du Pont 9923	110	100-110-120	10	5-10-15
ESL 2311	120	100-120-140	10	5-10-15
Cermalloy 7029	150	140-150-160	10	5-10-15

Key: (A) Conditions
(B) Type of paste
(C) Drying temperature (°C)
(D) Duration (min)
(E) Suggested
(F) Tried

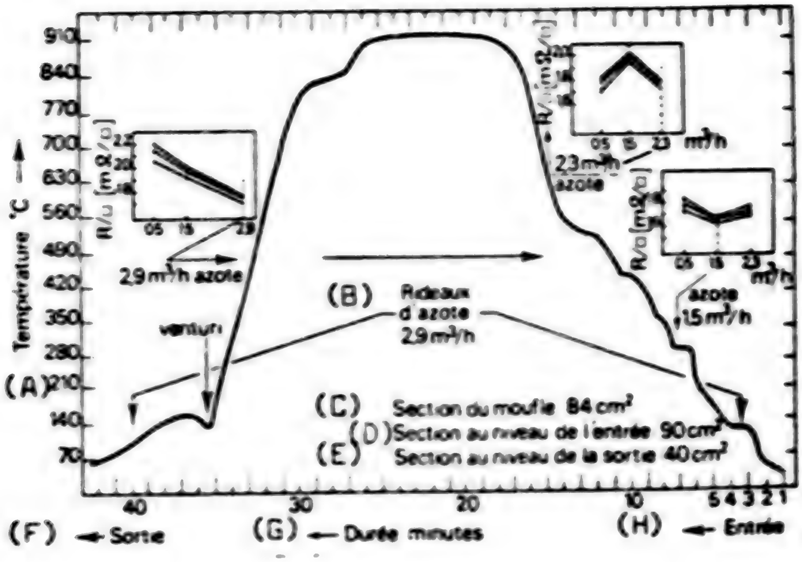


Figure 6. Temperature profile and nitrogen flow rates.

Key: (A) Temperature (^{0}C)
- (B) Nitrogen curtains
- (C) Furnace tube cross section: 84 cm^2
- (D) Inlet cross section: 90 cm^2
- (E) Outlet cross section: 40 cm^2
- (F) Outlet
- (G) Duration (minutes)
- (H) Inlet
- (I) Azote = nitrogen

The baking curve is shown in figure 6. Resistivities are measured on two 254 µm-wide conductors of four parts (eight values per point). An inert load equivalent to 1 m of belt is placed ahead of and behind each lot of parts. Very high sensitivity to nitrogen flow rates was noted for the following zones:

Extraction venturi in the baking zone (no longer being used);
Flow rates in the case of furnace tube isolation.

An installation for oxygen insertion is currently operational; it permits us to raise the O_2 concentration profile throughout the length of the furnace. At 900 ^{0}C, we obtain 20.10^{-6} oxygen in the entire baking zone.

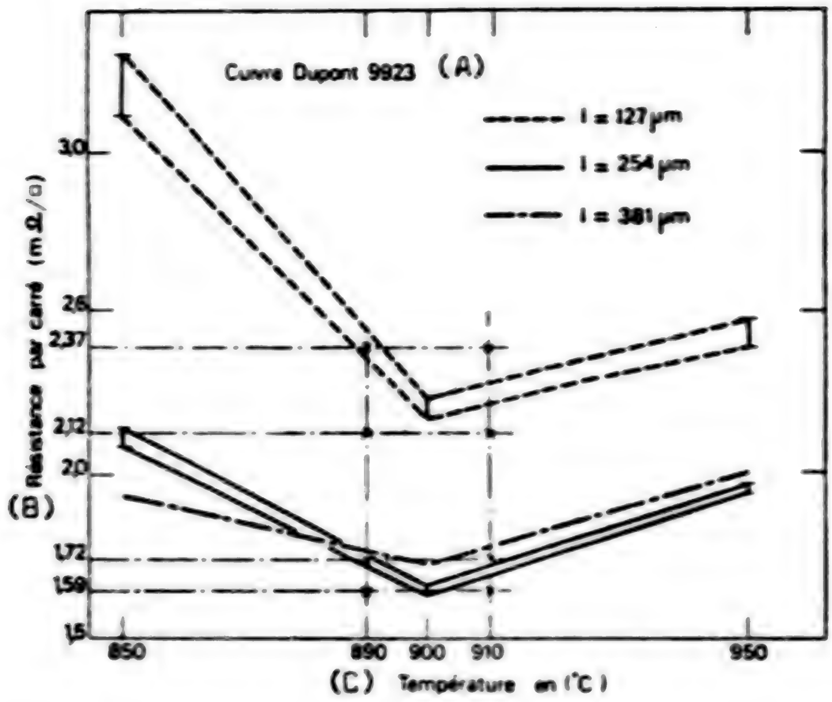


Figure 7. Resistance per square as a function of flat zone temperature.

Key: (A) Dupont copper 9923
(B) Resistance per square
(C) Temperature

The influence of the peak temperature was evaluated at ± 50 °C around 900 °C. This test was conducted only for the Du Pont copper because its resistivity was lower than that of LEP. Figure 7 shows a strong sensitivity to temperature, particularly for narrow widths.

Adhesion was measured by the peeling method for sample surfaces identical to those adapted by Du Pont (4.12 mm^2), which allowed us to make easier comparisons. We used an Istron machine with constant traction speed. Table X shows the minimal values and the averages for 30 values per case; we note that:

Tearing forces are lower than those claimed by suppliers;
Copper adheres much better to alumina than to the dielectric;
The ESL, and especially LEP pastes adhere better than the two others.

We observed no significant variations in R/□ and adhesion for as many as 14 rebakes.

Table X

Nom du fournisseur (A)	Force d'arrachement sur plot de 4,12 mm² (B) (kgf) minimale, maximale, moyenne		
	Cuivre/alumine (C) Cu_1	(D) Cuivre/diélectrique	
		$D_1 + Cu_2$	$Cu_1 + D_1 + D_2 + Cu_2$
Du Pont	0,7 / 1,5 } 0,94	0.5 / 0.96 } 0.66	0.55 / 0.73 } 0.61
ESL	0,9 / 2 } 1,32	0.8 / 1,9 } 0,95	0,5 / 1,6 } 0,80
Cermalloy	0.3 / 1.1 } 0,71	0,2 / 0.9 } 0,50	0,2 / 0,8 } 0,45
LEP	1.3 / 2.7 } 1.8	1 / 2.3 } 1,5	-

Key: (A) Supplier
(B) Tearing force for 4.12 mm^2 sample (kgf) minimum, maximum, average
(C) Copper/alumina
(D) Copper/dielectric

Properties of Dielectrics

The intrinsic characteristics of the dielectric were evaluated on capacitors with electrode areas in the ratios 1, 2, 4, and 25, beginning with an area of 1.6 mm^2. K-values are close to those announced by the vendor. The highest insulating resistances were found for the Du Pont dielectric ($> 1.10^{13}\Omega$). Breakdown voltages were always above 500 V; when changes in these voltages are plotted as a function of electrode areas (figure 8), the value of the holding voltage is reduced by only a small amount. The specific capacity for small cross sections is lower than 2.5 pF/mm^2, or about 0.08 pf per crossing (175 µm line).

The number of rebakes (up to 14) has little influence on the dielectric's properties, but this fact still has to be confirmed for 25 to 30 rebakes.

It should be pointed out that the dielectric acquires a gray pigmentation after the first bake; this pigmentation disappears during successive bakes, accompanied in some cases by swelling of the dielectric.

In conclusion, we have kept the Du Pont de Nemours system for qualification tests; the LEP copper is at least as good, but the dielectric is unavailable. We are currently evaluating the experimental dielectric of this laboratory.

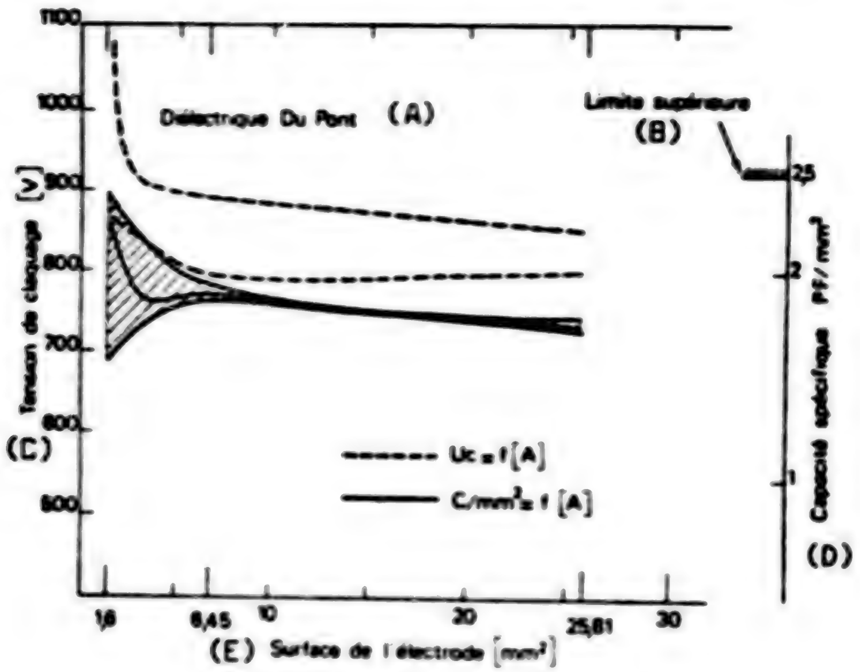


Figure 8. Breakdown voltage and specific capacity as a function of electrode area.

Key: (A) Du Pont dielectric
(B) Upper limit
(C) Breakdown voltage
(D) Specific capacity
(E) Electrode area

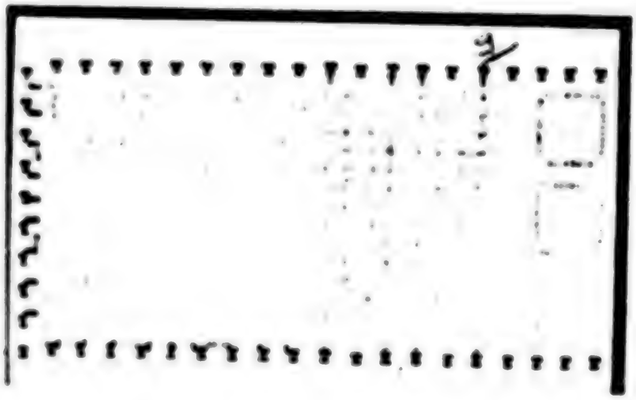


Figure 9. Test specimen used for qualification (50x25 mm substrate).

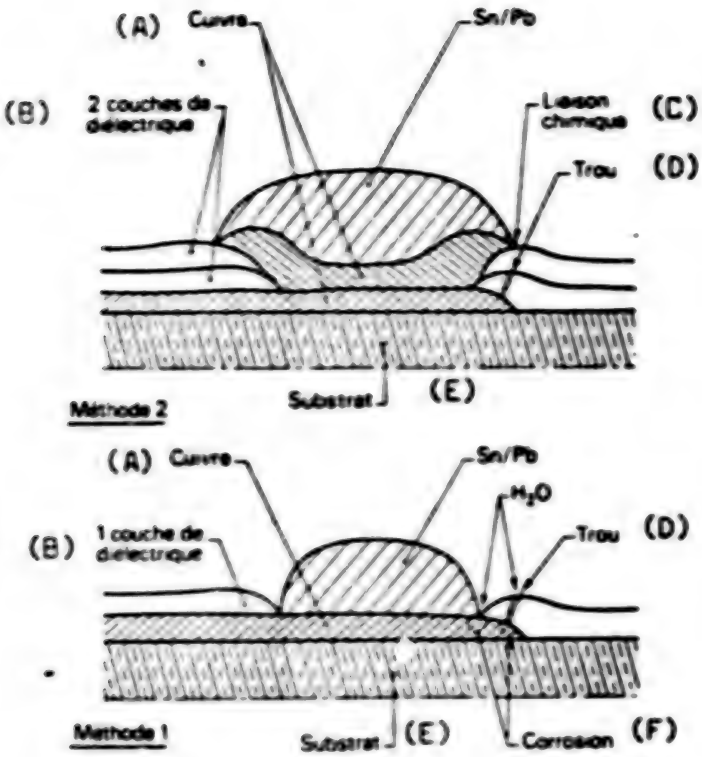


Figure 10. Cross section of the two methods of protection.

Key: (A) Copper
(B) Dielectric layer(s)
(C) Chemical bond
(D) Hole
(E) Substrate
(F) Corrosion

3. Qualification

For the qualification test we used a 350 µm step, or 2.86 lines/mm for a conductor width of 175 µm.

The photograph (figure 9) shows the various test possibilities:

Crossing matrix (900);
400 µm square window;
Contacts by brazing TAB to 40 outputs;
Output contacts (48).

Table XI

Nature of tests			Number of samples Passivated No 1	Passivation No 2
Group 0 (88 samples):				
Initial measurements:	Electrical		44	44
	Mechanical		--	--
Group 1 (18 samples):				
VRT 10, 20, 50 cycles:	-20/+70		3	3
	-40/+85		3	3
	-55/+125		3	3
Group 2 (20 samples):				
Wet heat 40 °C, 95% RH:	With applied voltage		5	5
	Without voltage		5	5
Intermediate measurements after 10, 21, and 56 days				
Group 3 (30 samples):				
Aging under voltage:	U_n = 60 V:	70°	5	5
		85°	5	5
		125°	5	5
Intermediate measurements at 500, 1000, and 2000 h				
Group 4 (20 samples):				
High temperature storage:	125°		5	5
	150°		5	5
Intermediate measurements at 500, 1000, and 2000 h				

We have looked at two passivation cases:

Case No 1: simple passivation (one dielectric layer to limit brazing surfaces;
Case No 2: special passivation with hermetic plug (two dielectric layers plus one Cu reload). As can be seen from figure 10, case No 1 provides only a mechanical contact between the passivation layer and the joint, while case No 2 results in a copper/dielectric chemical bond.

All layers were tinned after stripping with Solder Wet. The cleaning procedures have already been described.

The test design is shown in table XI.

No variations in the resistivity of the copper were found, but the adhesion measured as pure traction on 1 mm^2 contacts decreases very rapidly after 2000 h storage at 150 °C.

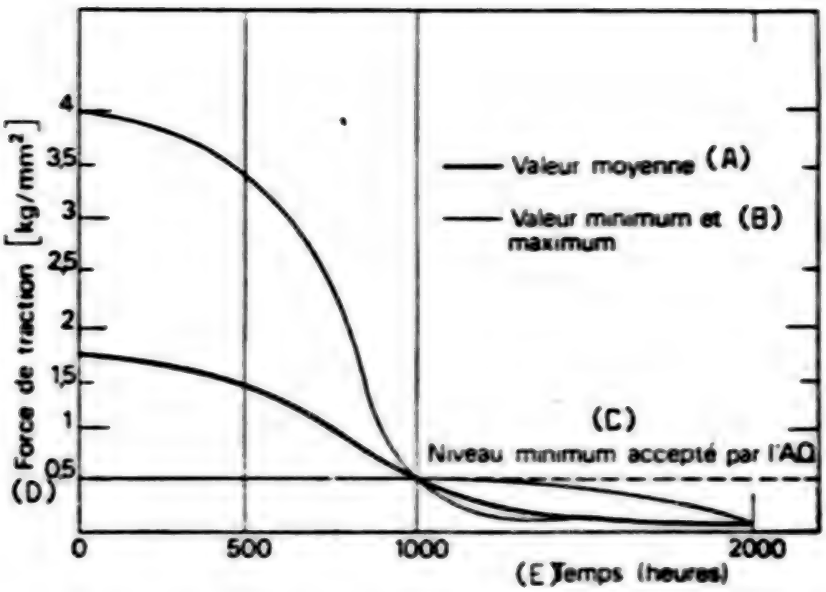


Figure 11. Aging at 150 °C.

Key: (A) Average value
(B) Minimum and maximum values
(C) Minimum level accepted by QC
(D) Traction force
(E) Time (hours)

As can be seen from figure 11, we are below the threshold of 0.5 kg/mm^2 accepted by our quality control. At 125 °C there is a slight decrease from 2.07 to 1.55 kg/mm^2 at 2000 hours.

After wet heat storage for 56 days at 40 °C and 95% RH, no decrease can be found in tearing force.

The behavior of the dielectric under the various constraints is excellent. Moreover, in the case of the special passivation, no corrosion pinholes were observed in the copper after wet heat.

4. Comparative Costs of Multilayer Devices Based on Gold and Copper

We have selected as working unit a multilayer device with two conductor levels on a 2" x 1" substrate. The nitrogen consumption per substrate is considered according to four assumptions:

Table XII

		(A) Hypothèse 1	(A) Hypothèse 2
Nombre de mètres cubes consommé par an...... (B)		7 920 h × 14.6 m³ = 115 630 m³	7 920 h × 14.6 m³ = 115 630 m³
(C) Coût de l'azote consommé par an (F) (¹)..........		80 940 F	80 940 F
Nombre de substrats produits par an (D)	$k = 0,62$...	1 617 h × 146 substrats/h = 236 080	4 620 h × 146 substrats/h = 674 520
	$k = 0,82$...	1 617 h × 219 substrats/h = 354 12[illegible]	4 620 h × 219 substrats/h = 1 011 780
(E) Coût de l'azote par substrats (F)	$k = 0,62$...	0,342	0,120
	$k = 0,82$...	0,228	0,080
(¹) Prix du mètre cube d'azote qualité « U » = 0,70 F/m³. (F)			

Key: (A) Assumption
(B) Number of cubic meters consumed per year
(C) Cost of nitrogen consumed per year (F) (1)
(D) Number of substrates produced per year
(E) Cost of nitrogen per substrate (F)
(F) (1) Price of "U" quality nitrogen = 0.70 F/m³.

Coefficient for filling the oven belt (t), defined as the substrate area passing through the furnace per unit time/belt area rolling during the same time. Two coefficients are used:

0.62 actual coefficient with automatic loading,
0.82 maximum coefficient with special automatic loading;

For an annual oven utilization of 7h/24, 5 days/week, 11 months,
20 h/24, 5 days/week, 11-12 months.

The nitrogen consumption of our six-zone BTU furnace, 10 cm wide by 6 m long, is 14.6 m^3/h.

Table XII shows the costs per substrate.

Table XIII

	(A) Multicouche/cuivre		(B) Multicouche/or	
	Cuivre 9923 (C)	Diélectrique 9049 (D)	Or 9791 (E)	Diélectrique 9429 (F)
(G) Quantité de pâte consommée (mg)	69	247	165	253
(H) Coût des pâtes (F/g)	9,94 (1)	6,21 (1)	52,44 (2)	5,03 (2)
(I) Coût des pâtes par substrat (F)	0,69	1,53	8,65	1,27
(J) Coût total des pâtes (F)	2,22		9,92	
(K) Coût de l'azote (F) :				
(L) 4 cuissons (sans passivation) Hyp. 1 $k = 0,62$	1,37			
Hyp. 1 $k = 0,82$	0,91			
Hyp. 2 $k = 0,62$	0,48			
Hyp. 2 $k = 0,82$	0,32			
(M) 7 cuissons (avec passivation) Hyp. 1 $k = 0,62$	2,39			
Hyp. 1 $k = 0,82$	1,60			
Hyp. 2 $k = 0,62$	0,84			
Hyp. 2 $k = 0,82$	0,56			
(N) Coût total sans passivation	2,54 à 3,59		9,92	
(O) Coût total avec passivation	2,78 à 4,61		9,92	

(P) (1) Ces prix ont été communiqués par Du Pont le 10 octobre 1977 pour « toutes quantités ».

(Q) (2) Ces prix ont été communiqués le 10 octobre 1977 pour des quantités de 300 g, qui sont les quantités habituelles de commande pour ce type de produit.

Key:
- (A) Multilayer/copper
- (B) Multilayer/gold
- (C) 9923 Copper
- (D) 9049 Dielectric
- (E) 9791 Gold
- (F) 9429 Dielectric
- (G) Quantity of past consumed (mg)
- (H) Cost of pastes (F/g)
- (I) Cost of pastes per substrate (F)
- (J) Total cost of pastes (F)
- (K) Cost of nitrogen (F)
- (L) Four bakes (without passivation)
- (M) Seven bakes (with passivation)

Key (continued):

(N) Total cost without passivation

(O) Total cost with passivation

(P) (1) These prices were provided by Du Pont on 10 October 1977 for "all quantities"

(Q) (2) These prices were provided on 10 October 1977 for 300 g quantities, which are the customary amounts for orders of these products

Table XIII shows that depending on the various calculation assumptions, the material costs are 2 to 3.5 times lower than those required for gold based multilayers. We believe that the manpower costs are the same as those required for gold multilayers, but this is not strictly accurate because each layer must be baked separately. On the other hand, several solutions are available to reduce the production cost of copper multilayers.

The nitrogen consumption can be reduced, partly by controlling the oxygen concentration in the baking zone, and partly by reducing the flow by two or four during non-working days. At the same time, the furnace lengths can be increased without increasing the nitrogen consumption, thereby increasing the production capability.

And finally, the price of copper pastes included a large portion of manpower and is not primarily dependent on the high cost of precious metals, all of which will contribute to reduce the cost of manpower units.

5. Conclusions

Knowing the thermodynamic limits of the solid phase reaction of copper, and having verified the sensitivity of copper conductors to baking, we were able to adopt the Du Pont copper + Du Pont dielectric system after preliminary characterization tests. The complete tests were carried out on qualification samples with two levels of conductors, rather comparable to those used by the paste suppliers (Du Pont, ESL, Cermalloy, Emca, TFS).

It is impossible to extrapolate these results to more than two levels; we have in fact fabricated more complex multilayers with four conductor levels, for which the yield was nearly zero. We are presently studying the causes for these failures:

Development of bubbles at the copper-dielectric interface;
Microcracks in the dielectric, associated with the previous failure.

The hypothesis offered by Du Pont is not acceptable in our opinion; it concerns the removal and progressive combustion of the heavy solvents (polymers). Several investigations were conducted in order to verify this hypothesis:

DTA thermal balance;
Elimination of solvents under vacuum;
Introduction of oxygen into the combustion zone of the oven (400 °C), up to $1000 \cdot 10^{-6}$;
Measurement of the dielectric recrystallization by X-rays;
Research into the possible solid phase reactions between copper and the dielectric, which could release gases (we have isolated a blue copper aluminate);
Research into the Kirkendall effect, which could lead to the creation of voids.

Up to now we have no absolutely sure conclusions, but we lean toward another system which would not practically present this failure: copper + LEP dielectric.

The formulation of this dielectric is indeed very different from the one formulated by Du Pont. This system still has to be completely qualified.

The applications of these copper-based multilayers are quite numerous in the tin field. The interest shown in chip-carriers for the encapsulation of intermediate and heavily integrated circuits, is totally associated with the development of multilayer interconnections solderable with tin-lead. On the other hand, the product of density, resistivity, and cost is much lower than that for gold conductors. Another non-trivial advantage for the user of these chip-carrier LSI's, is the possibility of multiple repairs of the macrocomponent (multilayer with n chip-carriers); this is possible for copper while it is very difficult for gold for the same level of quality.

In another domain, we are currently testing the system copper conductor + compatible resistances; this is opening an equally important field for analog applications.

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ITALY

CHARACTERISTICS, EFFICIENCY OF 'MODULAR ENGINES'

Turin ATA in Italian No 4, Apr 79 pp 177-184

[Article by Graduate Engineer Gian Luigi Berta, lecturer and professor in the Institute of Machinery of the University of Genoa, and Graduate Engineer Massimo Capobianco, fellow in the Institute of Machinery of the University of Genoa: "Experimental Investigation of the Energy Behavior of the Modular Engine"; work done within the framework of the Purpose-Directed Energy Project, Traction Subproject, of the CNR (National Research Council)]

[Text] 1. Introduction

The modular engine falls within the framework of the medium-term proposals for reduction of fuel consumption in road traction; it is based on the principle of grouping the cylinders of the internal-combustion engine into a number of modules activable to the extent needed for the power demanded, and thus providing regulation in the form of reduction [1].

The idea, originally born in 1973 [2], was subsequently put into the "Purpose-Directed Energy Project, Traction Subproject" of the National Research Council. For the time being, work is being done only on controlled-ignition engines, which have poorer efficiency at reduced load.

The experimental investigations carried out by the Institute of Machinery of Genoa in the first 2 years, articulated in bench tests and road tests, have aimed at the objective of quantifying the fuel savings to be achieved with this engine, adopting different techniques for deactivating the cylinders [3, 4, 5]: reduction of displacement, reduction of fuel-mixture flow, reduction of fuel.

It is pointed out that reduction of the displacement amounts to disconnecting the shaft linkage of the modules deactivated; the term "modular engine" was initially used for this technique only, and the term was later extended to all engines capable of regulation by reduction.

Reduction of fuel-mixture flow consists in preventing fuel-mixture cycling in the deactivated cylinders by keeping the relative intake and exhaust valves closed.

With reduction of fuel, on the other hand, only the supply of fuel is shut off, while a flow of air is permitted to cycle through the inactive modules.

The present article reports on the experimental results of the bench tests with regard to energy savings; as regards the practical construction aspects, the reader is referred to what has already been published [1].

2. Experimental Apparatus

2.1 Engines Used

For the bench-test research, Alfa Romeo 301.02 engines, with four opposed cylinders, were used, in the Institute of Machinery of Genoa. The choice of this engine was based on its equal phase-displacement conditions as well as on its conditions of balance of alternative torques and forces for the various modules in the case of displacement reduction; in this regard, the "boxer" engines are especially well-suited, since they can be broken down into two-cylinder modules with opposed cylinders [1]. The total displacement (≈ 1,200 cc) would not be the most successful for road use [6]; but for bench study of the behavior of the engine, the absolute power values are of no interest whatsoever. Although the motors used in the 2 years of research, which will be designated as engine A and engine B, respectively, are of the same type, there are slight differences between them, especially as regards the timing diagram; the characteristics of the two engines, as well as the fuel-supply systems adopted, are given in Table 1.

Table 1--Characteristics of the Engines Used

			Engine A	Engine B
number of cylinders			4	4
number of modules			2	2
total displacement (cc)		V_t	1,186	1,186
stroke/bore ratio		S/D	0.738	0.738
intake valve diameter/bore ratio		d_a/D	0.475	0.475
exhaust valve diameter/bore ratio		d_s/D	0.405	0.405
number of carburetors			2 single-barrel	2 two-barrel, synchronized
make and model of carburetors			Weber 28 IMB	Weber 36 WX 829/1 & /2
butterfly valve diameter/bore ratio		d_f/D	0.35	0.45
carburetor choke diameter/bore ratio		d_v/D	0.287	0.4
valve timing:				
- intake	beginning before top dead center		6°	12°
	ending after bottom dead center		54°	48°
- exhaust	beginning before bottom dead center		54°	45°
	ending after top dead center		6°	7°

2.2 Modularization of the Fuel-Mixture Cycling Systems

The engines used were first modified to make the flow of combustion mixture into the two modules independent (modularization of the fuel-mixture cycling systems). In the two engines, A and B, the same configuration was maintained for the exhaust system, but the system was modified from the original one by the adoption of twin manifolds [3, 4].

As regards the intake system, a solution was first sought that would accelerate fuel-mixture tuning (engine A). A manifold composed of four branches connected in pairs was adopted for each two-cylinder unit, a single-barrel carburetor available in the market and normally used on a two-cylinder engine of corresponding unit displacement was used. This system, while giving the engine high operational elasticity, put a penalty on its maximum power, since both the diameter of the butterfly valve d_f and the diameter of the choke d_v (not interchangeable) were distinctly undersized in relation to the engine's requirements.

As the research was carried out, the suspicion arose that some negative results, especially in fuel reduction, were produced by excessive throttling of the intake. Hence it was felt necessary to fit engine B with a fuel-supply configuration system capable of minimizing the pumping losses and ensuring optimum filling at high speed [4]. Therefore two carburetors of the inverted double-barrel type, with simultaneous opening, were adopted and mounted on the heads with short unheated headers (Figure 1); a system ensuring perfect synchronization of the butterfly valves was also installed, since the investigation into fuel reduction had gone in the direction of synchronization [1, 4].

Special care was taken with the tuning of the fuel-supply system for both engines. The quality of the mixture was regulated in such a way as to reproduce the production-model engine's behavior as faithfully as possible, as regards consumption, throughout its entire operating range; where this was not possible, it was preferred to have a slightly lean mixture for the operating range. As regards scattering of mixture quality among the various cylinders, it was attempted to keep it to a minimum, and it was in every case kept lower than it proved to be in the production-model engine. For this purpose, the CO and HC emissions were measured at the exhaust from the various cylinders separately, in an attempt to eliminate any disuniformities affecting the regulation of the carburetors.

For the ignition advance, an increase of the fixed advance had to be used in reduction in order to compensate for the drop of this parameter in comparison with the production-model engine owing to the lower vacuum at intake.

2.3 Deactivation of the [illegible] Module

Since the research did not have the purpose of developing the modular engine industrially, but rather of comparing various reduction techniques, to bring out their respective advantages, several measures were taken to enable the engines to operate under partial activation.

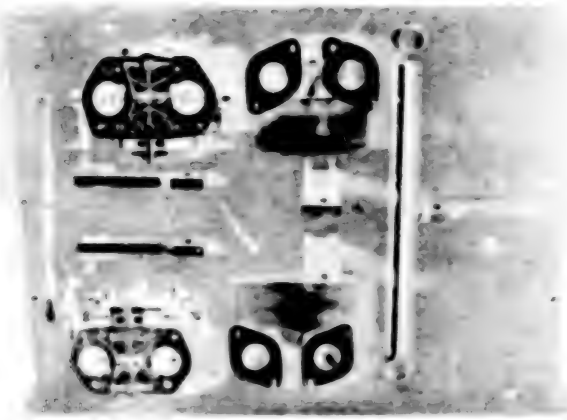

Figure 1--Components of the fuel-supply system of engine B

For engine A, fuel reduction was achieved by cutting off the supply of gasoline to the carburetor feeding the module to be deactivated (cylinders 1 and 2 [3, 4]). For engine B, on which each carburetor serves one cylinder of each module, blind main and idling jets were used on the barrels going to the cylinders to be shut off from operation; nothing was done with the accelerator pump, since it had been observed that it does not act under test-bench conditions, but the priming tubes of the power jets were taken out.

Reduction of fuel-mixture flow, on the other hand, was achieved for both engines by removing, on the lathe, the cam disks for the valves of the cylinders to be deactivated.

Finally, for reduction of displacement, since no intermodular coupling was available, the pistons and connecting rods of the two cylinders concerned were removed, and lubricating oil was prevented from coming out of the rod-journal holes on the crankshaft by the use of metal ties taken out of the connecting rods of the engine itself and fastened with pins put into the holes of the crankshaft journals.

2.4 Measuring Instruments

All the experimental observations were made using the double test bench of the laboratory of the Institute of Machinery of Genoa (Figure 2), which is equipped with temperature regulators. For measurement of engine torque, an eddy-current electromagnetic brake was used; angular velocity was measured with a digital frequency meter connected to the brake's tachimetric alternator.

For fuel flow, the calibrated-bubble volumetric system, coupled with a digital electronic timer, was used. For the air flow, an Alcock viscous-flow gauge was used, while the concentrations were determined with an infrared-type nondispersive analyzer.

Figure 2--Modular engine on the bench in the laboratory of the Institute of Machinery of the University of Genoa (engine A)

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3. Experimental Results

Measurements of power and fuel consumption were made throughout the entire operating range, with systematic variation of engine rotating speed and load. The characteristic range for urban use [1, 6]--moderate speed and medium-low load--was explored with particular attention.

Both with engine A and with engine B, the procedure was repeated four times: with full activation, and with the engine reduced to 1/2 activation level, in each of the three modes.

3.1 Efficiency Characteristics with Regulation

The evidence of the improvements made by reduction regulation in the efficiency characteristics under regulation are given in Figure 3, which shows the ratio between general overall efficiency η_g and its highest value η^*_g at the same engine speed, in function of the ratio between general effective power P_e and its value P_{oe} at full opening with activation level 1/1, at equal speed.

The engine speed chosen as an example is a little less than half of the maximum [1], and proves quite representative of urban conditions of automobile use.

The three reduction techniques (fuel, fuel-mixture flow, and displacement) are represented together in the figure; and the observations for engine A and engine B, whose behavior is sufficiently similar to permit the drawing of common interpretive curves, are superimposed.

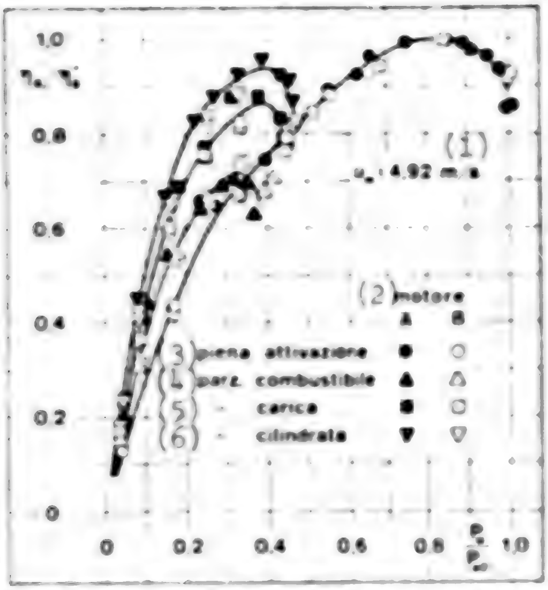

Figure 3--Characteristics of overall efficiency with reduced load, at constant engine speed: the conventional engine (full activation) is compared with the reduced engine, at 1/2 activity level, for each of the three techniques.

Key:

1. Meters per second
2. Engine
3. Full activation
4. Fuel reduction
5. Fuel-mixture flow reduction
6. Displacement reduction

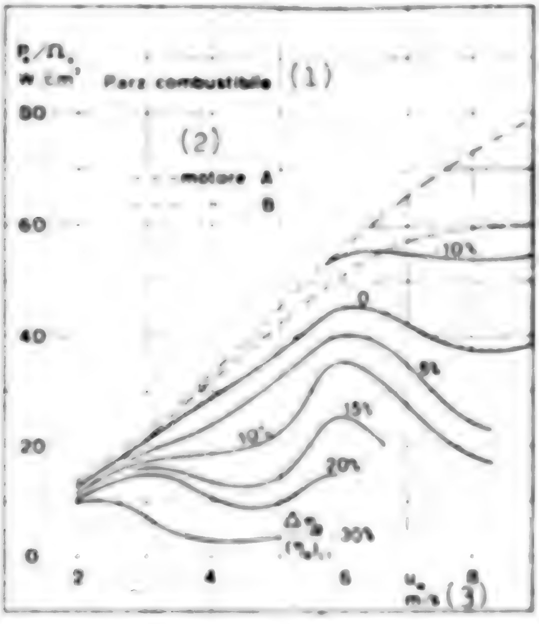

Figure 4--Increase in overall efficiency of fuel-reduced engine (1/2 activation level) as compared with conventional engine.

Key:

1. Fuel reduction
2. Engine
3. Meters per second

Reduction of the number of active cylinders permits repetition, at P_e/P_{eo} loads less than 1/2, of efficiency values close to the maximum, which with conventional engines is found only at high load. It can be seen that for all the ways of reducing, the advantages[2] increase with decrease of load, and gradually drop to nil in the proximity of the maximum opening of the lamination organ of the reduced engine.

The efficiency values η_g that can be reached with the three techniques, at equal power P_e, are very different: as anticipated [1], the results for fuel reduction are modest, those for fuel-mixture flow reduction are considerable, and those for displacement reduction are decidedly better.

The differences are due to the persistence of several sources of lost work in the deactivated module: mechanical losses (friction on pistons, piston rings, rod bearings) for fuel-mixture flow reduction, and in addition, pumping losses with fuel reduction. Homologous points, characterized by equal fuel-supply conditions, show different values of P_e[3] and of overall efficiency η_g, but are on the same straight line passing through the origin of the axes (see Appendix). Notwithstanding the strong reductions of η_g between homologous points as one goes from a more efficient solution to a less efficient one (for example, from displacement reduction to reduction of fuel-mixture flow), one still manages to save fuel by comparison with the conventional engine because, with P_e reduced simultaneously, the conventional engine's η_g fell also.

Thinking, on the other hand, in terms of equal effective power P_e, for the least-preferred reduction--fuel reduction--for example, one recognizes that even if one continues to cycle air through the inactive cylinders, the sum total of lost work through pumping in the two modules is less with reduction than with full activation, since the throttling organ has to be kept far more open in order to obtain the same P_e; and one also recognizes that the mechanical losses should not differ much in the two cases [3], except for the effects of the different heat regime of the inactive module, and that further reduction of losses can be hoped for, thanks to the reduced surface area for heat exchange, containment of the fraction of residual gases, and the higher combustion pressures[4]. However, in the proximity of the maximum P_e/P_{eo} value achievable with reduction, because of the necessity of enriching the mixture to ensure proper functioning at high values of mean pressure indicated, superiority lies with the conventional engine, which runs at the same P_e with the more economical quality of mixture.

By analogous reasoning, one deduces that the superiority of fuel-mixture flow reduction, and of displacement reduction over this, is attenuated, under comparison at equal P_e, by the necessity of throttling the intake more. Nonetheless, the enormity of the difference in η_g underlines the importance of the losses excluded--for example, the mechanical losses as one goes from fuel-mixture flow reduction to displacement reduction[5].

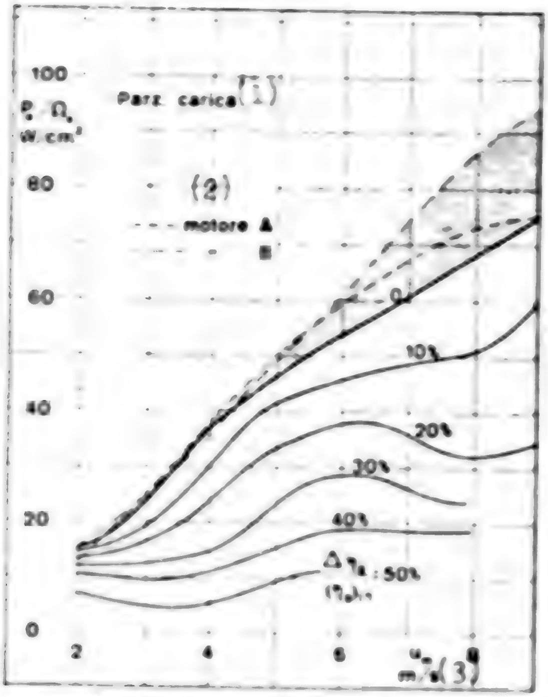

Figure 5--Increase in overall efficiency of engine with fuel-mixture flow reduction (1/2 activity level) by comparison with conventional engine.

Key:

1. Fuel-mixture flow reduction. 2. Engine 3. Meters per second

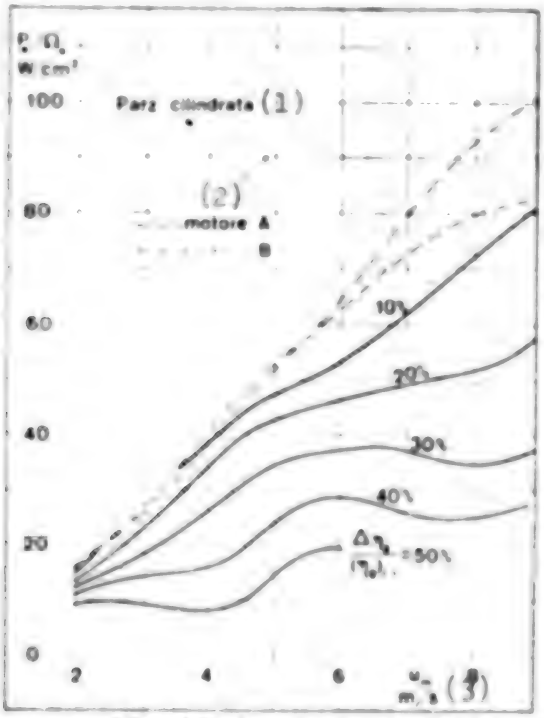

Figure 6--Increase in overall efficiency of displacement-reduced engine (1/2 activity level) by comparison with conventional engine.

Key:

1. Displacement reduction 2. Engine 3. Meters per second

3.2 Variations of Efficiency at Equal Speed

The effect of engine speed is illustrated in Figures 4, 5 and 6. Mean piston speed u_m and thermomechanical load P_e/Ω_s, always evaluated with reference to the Ω_s of the complete engine[6], are shown on the axes.

The curves for power at full opening are drawn for engines A and B, delimiting the range in which operation at both 1/1 and 1/2 activity levels is possible. Engine B has higher power and lower elasticity: only with fuel reduction do the lower pumping losses make $P_{eB} > P_{eA}$ possible even at low u_m.

Evaluation was made of the gain in overall efficiency η_g when one goes from the conventional engine to the reduced engine and compares, at equal power P_e and equal angular velocity ω[7], the overall efficiency at activity level 1/1 $(\eta_g)_{1/1}$ with the overall efficiency at 1/2 activation $(\eta_g)_{1/2}$[8].

The parameter $\frac{\Delta\eta_g}{(\eta_g)_{1/1}} = \left[\frac{(\eta_g)_{1/2} - (\eta_g)_{1/1}}{(\eta_g)_{1/1}}\right]_{P_e,\,\omega}$ was calculated thus, point by point.

Mainly because of the different carburation systems, slight differences were encountered between the two engines[9]: the arithmetic mean, which is represented in function of u_m and P_e/Ω_s through waveform graphs, was taken for consideration. It is encouraging to note that with fuel reduction under heavy load and at high speed, where it was feared with engine A that this technique would be penalized with an excessively choked fuel-supply system, nearly identical results were obtained with engine B, at equal P_e and ω [4]: it matters little, in terms of efficiency, whether the throttling is done by the butterfly valve or by a small-diameter tube.

Figures 4 and 5 show that part of the operating range in which the efficiency η_g of the conventional engine proves higher to η_g of the reduced engine; under these conditions it will be advisable to prohibit 1/2-activity level operation.

In Figure 4, the "prohibited zone" shows considerable extension: the presence on the curve of a maximum P_e at $\Delta\eta_g$ at a still moderate speed value ($u_m \cong$ [illegible] meters per second) makes it clear that fuel reduction is effective only at low rotation speeds, and makes it advisable to rule out its use at high engine speed.

It is therefore advisable for the activation level to be governed [1] by an automatic device, in function of both load and speed.

The range to be prohibited with fuel-mixture flow reduction is much smaller (Figure 5): it could be sufficient to limit the maximum butterfly-valve opening under partial activation, and it is not out of the question that differentiated tuning of the two modules [1] could eliminate the "prohibited zone" altogether. As regards fuel economy, it appears that both manual and automatic activation could be used with this reduction technique.

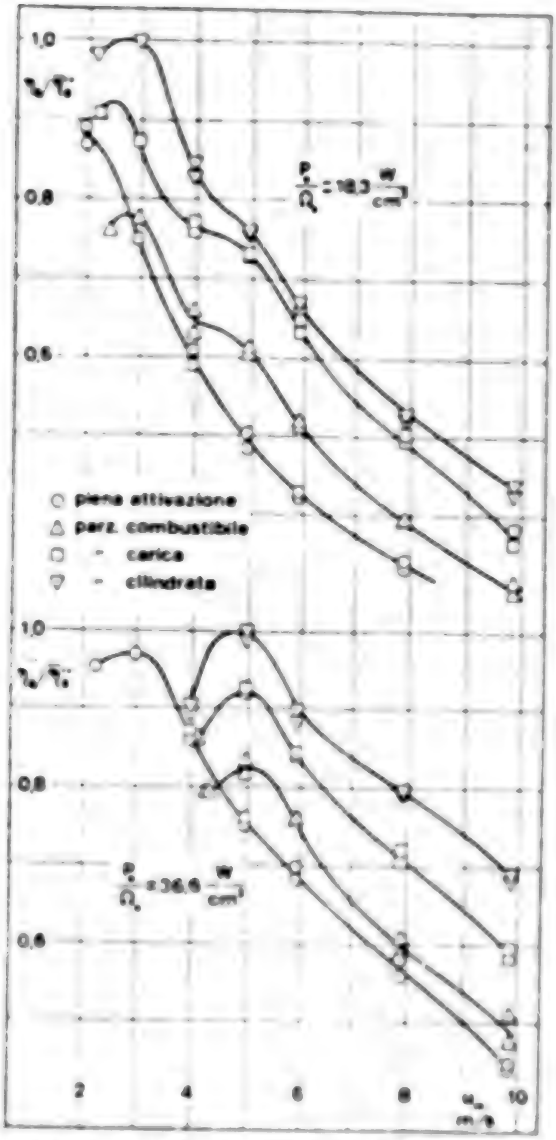

Figure 7--Evolution of overall efficiency at constant effective power in function of engine speed: the conventional engine (full activation) is compared with the reduced engine, with 1/2 activation level, according to each of the three techniques.

Key:

1. Full activation
2. Fuel reduction
3. Fuel-mixture flow reduction
4. Displacement reduction
5. Meters per second

On the other hand, it should be stressed that with displacement reduction, fuel is saved throughout the operating range[10], even though the increases in efficiency are very small at full opening.

The increase in the relative increment in overall efficiency with decrease of the thermomechanical load, which is characteristic of all three techniques, confirms that the advisability of adopting regulation by reduction increases with total displacement.

To quantify the advantages in the characteristic range of city driving, the different modes of use must be distinguished from one another. Under acceleration, given that the available power with reduction is sufficient [6], the increase in η_e proves minimal and is appreciable only for displacement reduction, and this is limited to vehicles with a high ratio between installed power and mass, P_{ei}/M_v.

With driving at constant speed, efficiency improves considerably: an average of about 20 percent for fuel reduction, almost 40 percent for fuel-mixture flow reduction, and more than 55 percent for displacement reduction.

It appears from the graphs that the effectiveness of reduction is highest at the lowest speeds; the fuel flow at the minimum regime in self-sustaining conditions is given in Table 3. It is significant that with displacement reduction, just a little more than half the amount of fuel is consumed as in the fully activated engine, which demonstrates that the sources of power loss that are not cut in half (auxiliary units, timing elements, etc) are negligible under this operating condition.

Table 3--Consumption under Minimum Regime

	Engine A		Engine B		
	n (RPM)	M_c (kg/hour)	n (RPM)	M_c (kg/hour)	$\Delta M_c/(M_c)_{1/1}$
Engine not reduced	875	0.498	850	0.449	--
Fuel reduction	885	0.511	940	0.448	-0.21
Fuel-mixture flow reduction	895	0.474	880	0.340	-0.34
Displacement reduction	900	0.343	880	0.291	-0.47

5.4 Effects of Engine Speed

The comparisons so far made between the modular and conventional engines, under the condition of equal rotational speed, are based on invariability of use conditions, on the assumption that identical transmission ratios are used in the same vehicle. However, especially in the case of manual control of the actuator, it may prove advisable to adopt different transmission ratios for a reducible engine [6]; it has even been noted during road tests that if this is not done, the driver is led, in some traffic situations, to go into different gears [5].

In both cases, the same use condition implies invariability of P_e only[11]; the modular engine will tend to operate at greater anguair velocity. Therefore

Figure 7 presents, on curves at constant P_e, the ratio between general overall efficiency η_g^{**}, and its highest value among all the solutions considered η_g at the same P_e, in function of mean piston speed u_m; the values of P_e/Ω_s chosen, to which correspond $P_e/P_{eM} = 0.13$ and $P_e/P_{eM} = 0.065$ for the engine in question, are very representative of urban use, with weak acceleration and at constant speed.

The evolution of the curves appears fully in agreement with the known levels cited for specific consumptions [1, 3, 10, 11, 6]. The particular value of P_e/Ω_s seems to penalize displacement reduction at lowest power, which disagrees with the second graph: this fact is to be attributed to discontinuity of carburation[12].

Hypothesizing the coupling of the modular engine with a conventional transmission in steps, one notes that with fuel reduction, the advantage over the conventional engine disappears if rotational speed increases even a little, so that if the immediately lower gear is used--with the ratio at the rear end remaining the same--lower efficiency η_g is obtained; and this confirms again the necessity of an automatic governor for the actuator. The displacement-reduced engine, on the other hand, continues to consume less fuel than at full activation with the use of a higher gear, but the variation $\Delta\eta_g$ is greatly reduced from what is shown in Figure 6.

In Figure 7, the influence of the alteration of several gear ratios, as suggested in [4], could also be isolated.

On the other hand, as regards the coupling of a modular engine with a high-efficiency continuous transmission adjusted in such a way as to make the engine operate at the rotational speed ω^{**} at which, for each value of required P_e, efficiency η_g^{**} is reached, new conclusions are drawn for the three reduction techniques.

If ideal conditions are placed on the transmission gap, fuel reduction proves entirely useless; but if one takes into account the fact that in the present state of the art the gap is very limited [13, 14], and one uses the partial-activation engine for those values of P_e for which $\omega > \omega^{**}$ results at full activation, the technique in question can produce some benefit.

But better results can be expected from fuel-mixture flow reduction, with which one could succeed in compensating fairly well, especially as regards relative simplicity of construction, for the practical limitations of the continuous transmission; in the ideal case of unlimited gap only at very low values of P_e, one would have the advantage of efficiency η_g^{**} which is superior--but only slightly so--to that of the conventional engine.

On the other hand, coupling a continuous transmission to a displacement-reduced engine seems an optimal solution, from the energy point of view. For low values of the ratio P_e/P_{eM}, no matter what the transmission gap, one could have lower consumption than with an engine regulated by lamination only; by simply taking advantage of this possibility, it can be hoped that activation

levels 1/2 and 1/3 only can make it possible to run the engine in the best way between $(\eta_g^{**})_{1/2}$ and $(\eta_g^{**})_{1/3}$ with practical gap values, throughout the range of required power levels.

It is clear that such a possibility could be fully taken advantage of only with automatic control of the activation of the power module, in contrast to what has been maintained so far with reference to the use of conventional transmissions [3, 5].

8. Conclusion

On the basis of the observations made on two four-cylinder, controlled-ignition modular engines, driving situation operational ranges and energy savings were determined for 1/2 activation by three reduction techniques.

With fuel reduction, modest results are accompanied by considerable constructional simplicity, without appreciable added costs for engines equipped with electronic ignition [1, 15, 16].

Reduction of fuel-mixture flow permits greater savings, so that it appears quite promising--except for several remaining doubts to be cleared up regarding emissions [5]--for short-term realization, inasmuch as it does not require redesign of the entire engine.

Far superior are the benefits offered by displacement reduction, as demonstrated by road tests carried out within the framework of this research and to be reported on shortly. The necessity of radical redesign for such an engine, together with the time needed for developing and testing the intermodular coupling [4], doubtlessly puts the application possibilities some time into the future, while the incidence of the construction costs of this mechanically more complex approach still remains to be evaluated.

Nevertheless, combination of the displacement-reduction technique with other techniques developed within the framework of the Traction Subproject--high-efficiency continuous transmission and the aerodynamic automobile [17]--appears promising.

Appendix

Identification of Homologous Operating Conditions

For a modular engine with equal modules, on the assumption that the indicated mechanical pressures p_{mi} of all the active cylinders are identical, the indicated powers P_i, in homologous operating conditions, or with the same fuel-supply conditions at the same angular velocity, will stand to one another in the ratio of the activation levels

$$\frac{P_{ia}}{P_{ib}} = \frac{p_{mi}\, z_a}{p_{mi}\, z_b} = \frac{a}{b}$$

The limit efficiency η_L and the external efficiency η_i will prove equal :

$$(\eta_L \eta_i)_A = (\eta_L \eta_i)_B$$

Keeping in mind that

$$\frac{P_i}{P_e} = \frac{1}{\eta_m} = \frac{\eta_L \eta_i}{\eta_g}$$

the representative points of P_i for different activity levels, A' and B', are individuated (Figure 8). As one goes from one solution to another which eliminates losses from the deactivated modules to a different degree, the constancy

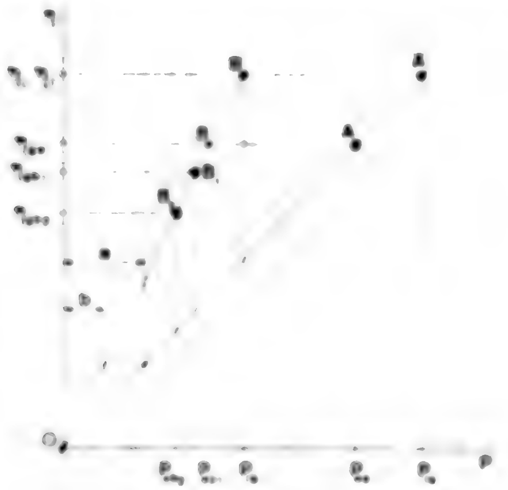

Figure 8

of η_L and η_i makes for the proportionality between P_e and η_g (points B_1 [illegible]). This demonstrates that the homologous points are on the same straight line passing through the origin of the axes. The similarity of the triangles [illegible] and A'B' [illegible] obviously permits identification of the homologous points without taking the indicated powers into account.

Notes

The authors wish to extend their warm thanks to Prof Ing [illegible] for his valuable advice and encouragement in the course of the research.

Special acknowledgement goes to [illegible], who, though not directly involved in the [illegible]-Directed Project, furnished and tuned the carburetors for engine B absolutely free of charge.

FOOTNOTES

1. The ratio with the maximum-power speed is n/n_T = 0.475 for engine A, and n/n_T = 0.35 for engine B.

2. Since the modular engine too functions in an entirely conventional manner when regulated by lamination only at full activation, the advantages of reduction can be deduced by comparing the engine under partial activation, no matter which reduction technique is used, with the same engine under full activation.

3. Unless there are effects of a secondary order, the indicated power P_i in the active cylinders is equal.

4. In this respect, much depends on the value of the conventional engine's ignition advance: a "developed" configuration of the advance, with θ_o optimized throughout the operating range, could make such advantage disappear, except in the vicinity of a self-sustaining condition.

5. For analysis of the losses which persist in this latter case, see the full discussion in [7].

6. The value of the total piston area was assumed not only for full activation but also in the case of partial activation, so as to be able to represent by a single point conditions of equal power requirement for the conventional engine and the reduced engine.

7. For the same engine, equality of P_e/Ω_s and u_m corresponds to equality of P_e and ω. To the meaning drawn from the theory of similarity, this comparison adds the meaning of identical condition of use [6].

8. The comparison of each engine with itself guarantees that the gains observed are not influenced by systematic differences in calibration, especially of carburation, and of ignition advance, or, if engines of different construction were involved, by the effect of different architecture.

9. The discontinuities of air-fuel ratio produced by the action of the progression holes [fori di progressione] [8], with both 1/1 and 1/2 activation, are mainly responsible for these differences.

10. A few measurements characterized by $\Delta\eta_g < 0$ at high u_m in engine A were not confirmed by engine B, and are therefore attributed to the fuel-system defects mentioned.

11. Prescinding from secondary effects: variation of equivalent mass, at the wheels, at the engine's moment of inertia [6], variation of overall transmission efficiency [9].

12. With strong choking at intake, the mechanical characteristics $P_e(\omega)$ at θ_r = constant present $P_e \cong$ constant over a wide interval of speeds [12]; along an isopower, therefore, it is credible that for a long stretch, the flow regime in the carburetor's progression system [sistema di progressione] is not very sensitive to engine speed.

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